THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

THE INSTITUTION OF

PRODUCTION ENGINEERS JOURNAL

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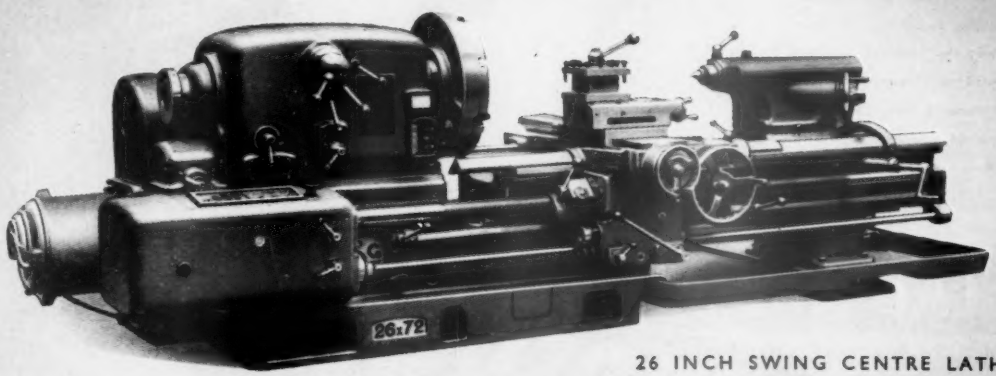

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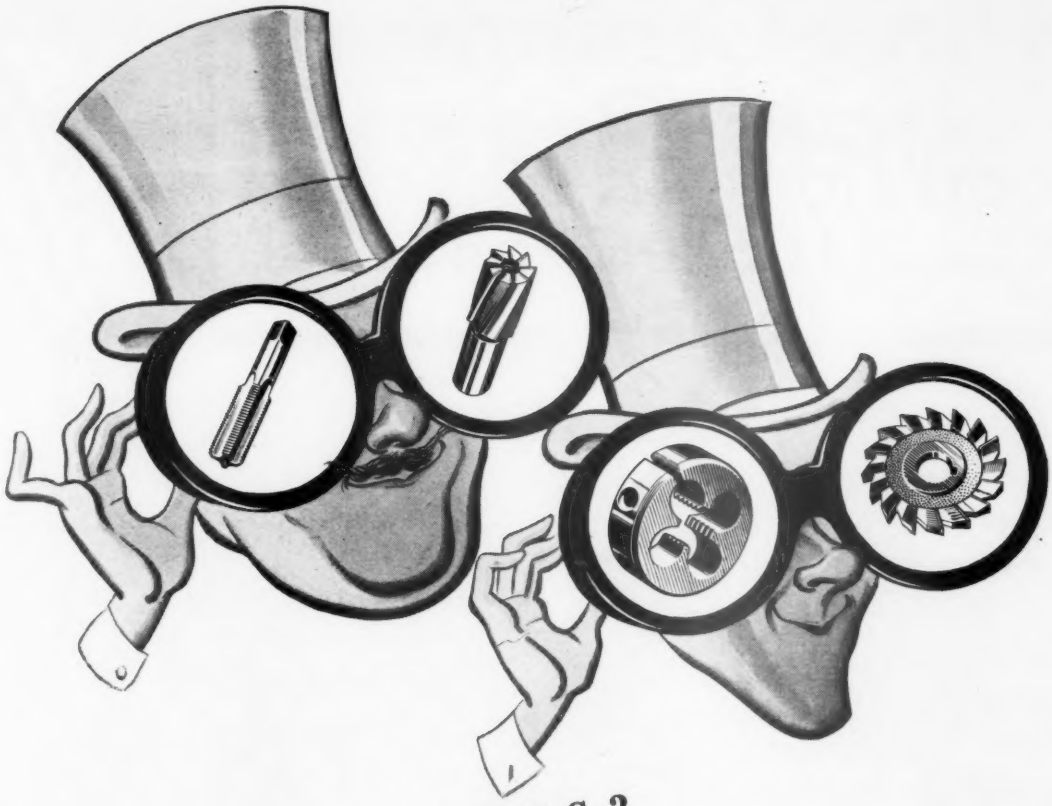

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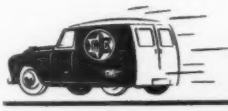

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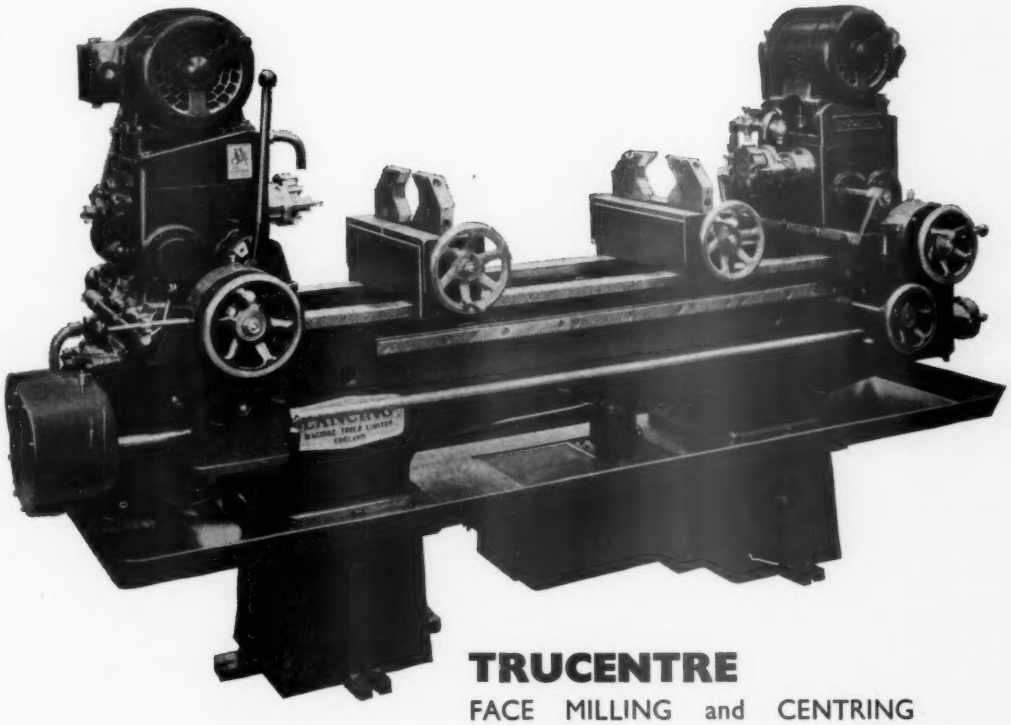

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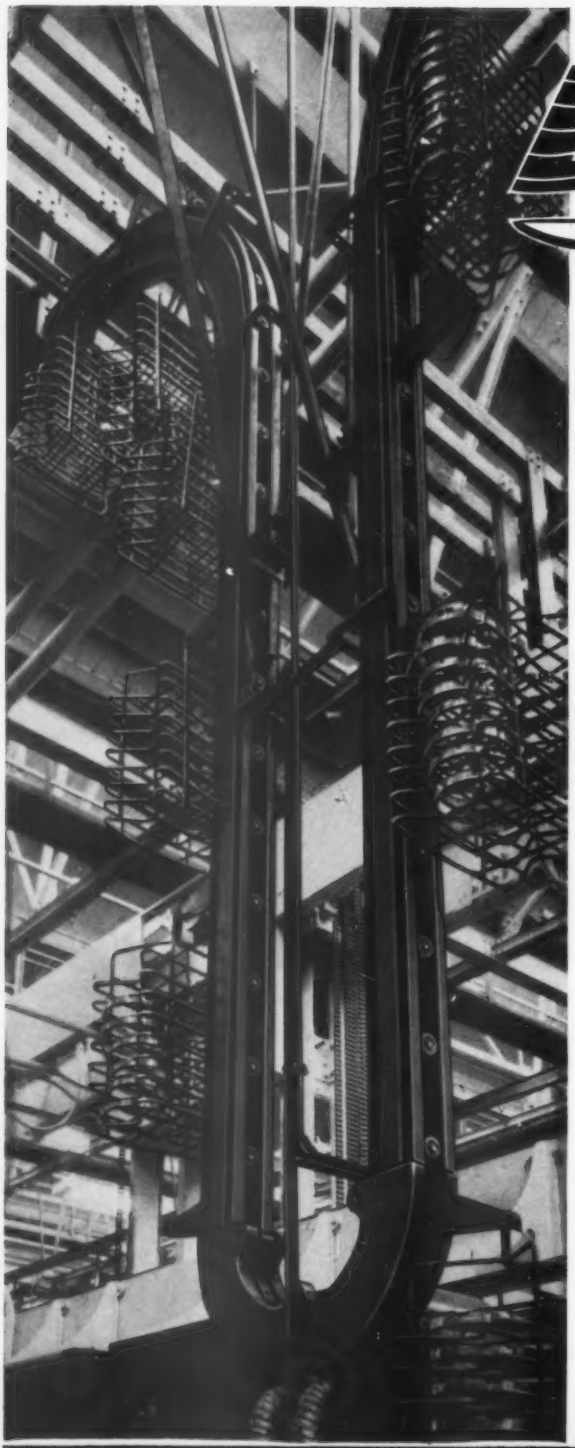

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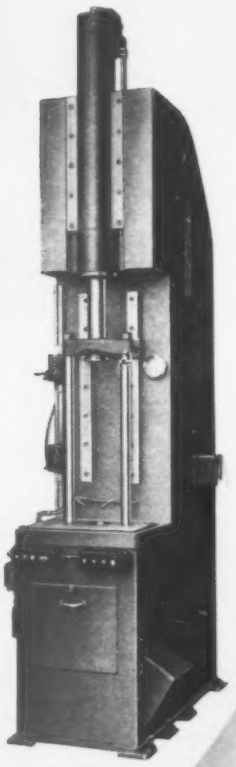

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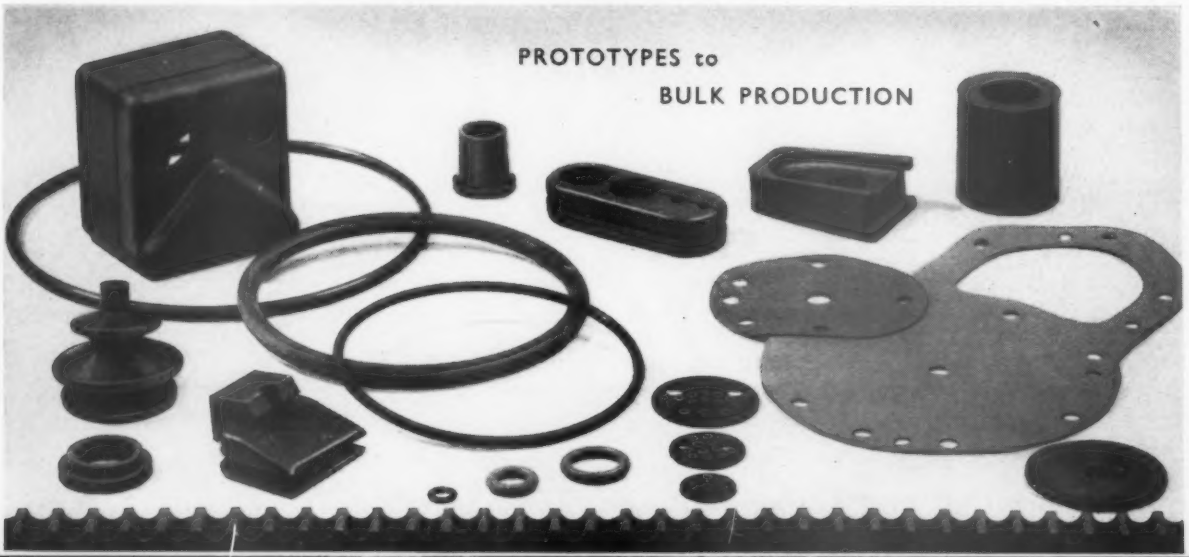

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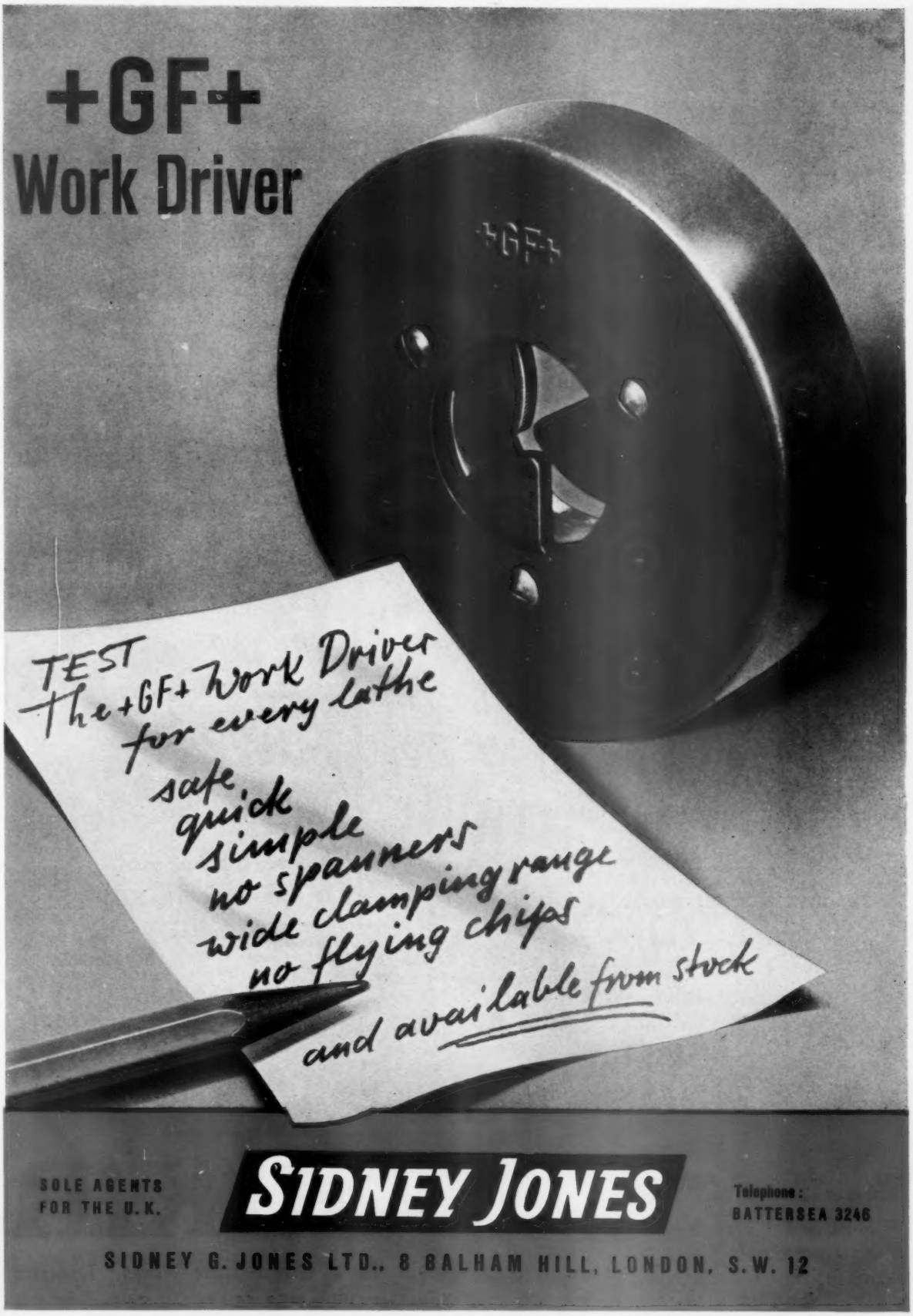
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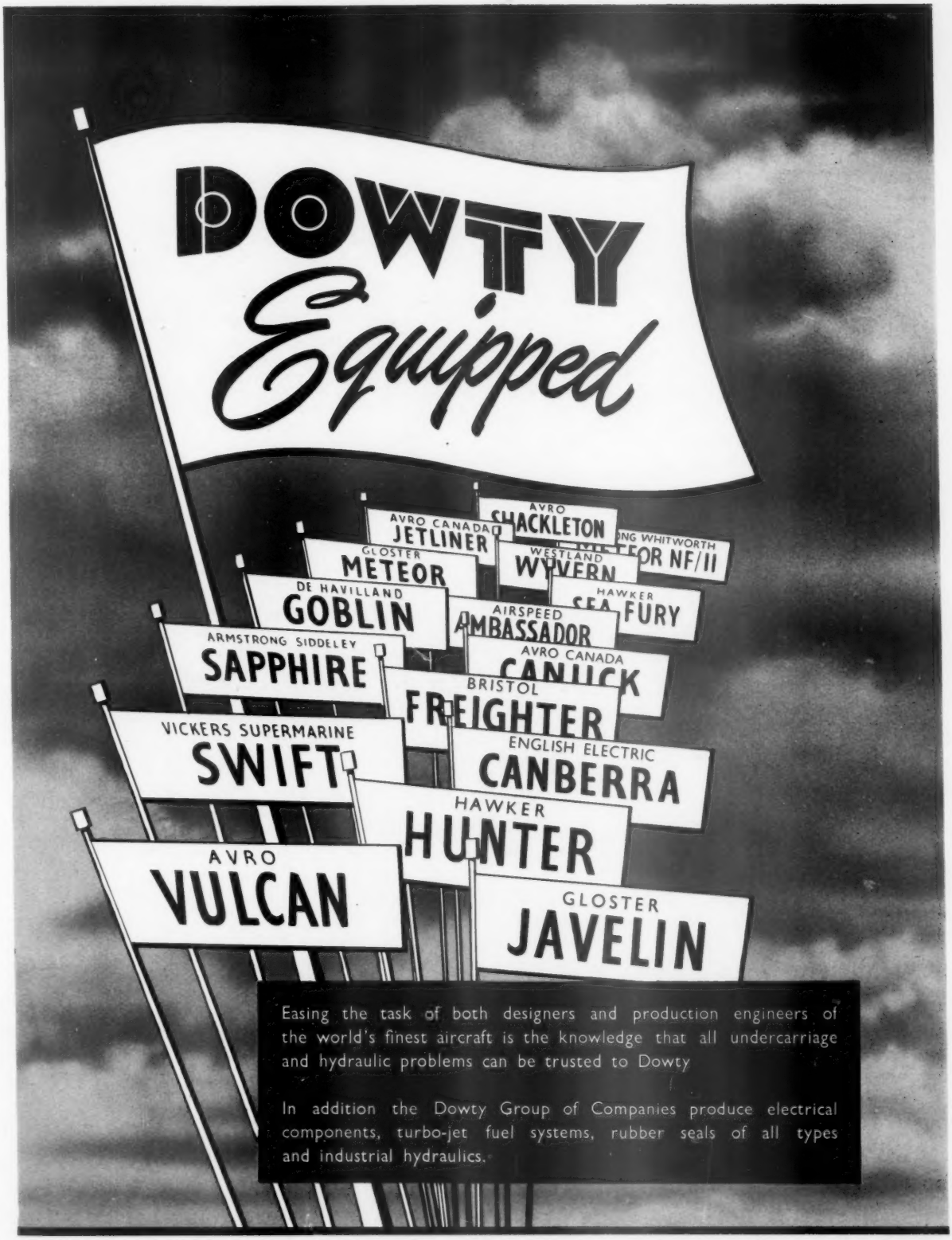
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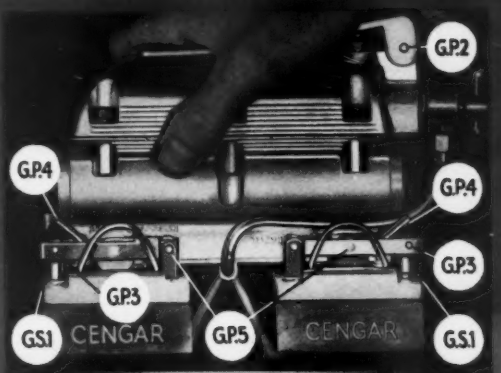

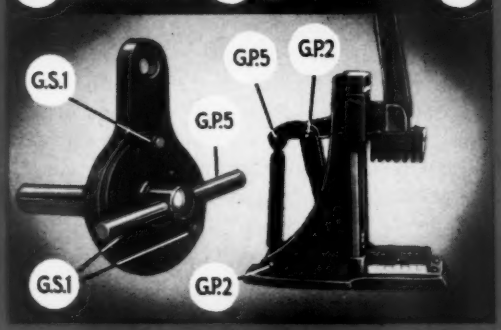

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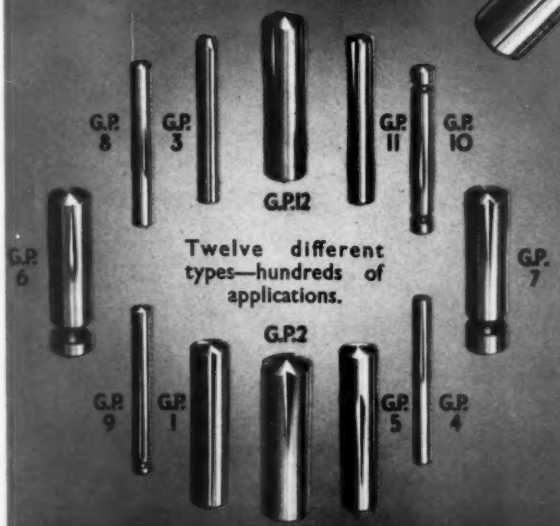

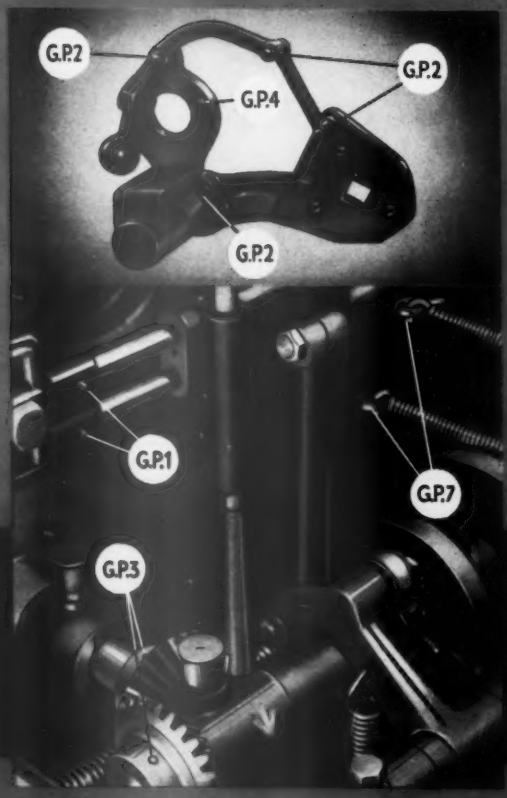

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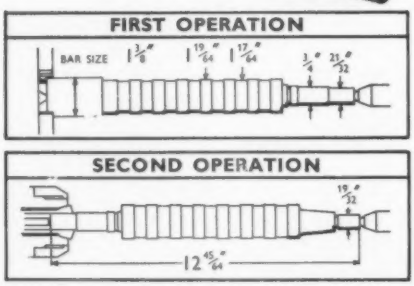

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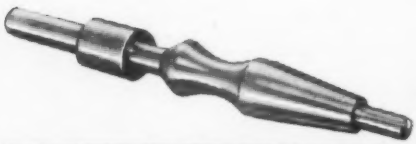

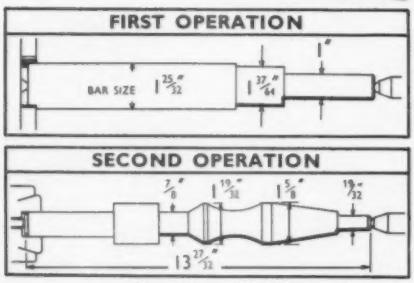

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The announcement was made in the New Year Honours List

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WALTER PUCKEY

The Institution of Production Engineers Journal
VOL. 33. NO. 2 FEBRUARY, 1954

Problems of Aircraft Production

by The Right Hon. LORD HAWKE.

Lord Hawke, a Lord-in-Waiting and spokesman for the Minister of Transport and Civil Aviation in the House of Lords, gave the opening address at the recent Conference on Problems of Aircraft Production organised by the Southern Section of the Institution at Southampton.

MY first duty is to thank you for an extremely pleasant lunch, and my next is to convey to you the apologies of Mr. Lennox-Boyd. He would very much like to have been here, but as Minister of Transport as well as of Civil Aviation he has to reply to a road debate in the House of Commons today. Unfortunately the Parliamentary Secretary who is particularly in charge of civil aviation matters, Mr. Profumo, was taken seriously ill a few days ago and has had to undergo an emergency operation. I am glad to say, however, that he is making good progress. You have therefore what I may perhaps describe as one of the Minister's Under-Lords, in default of an Over-Lord, in his place.

The Minister's Position

What is the position of my Minister? He is charged by statute with the general duty of organising, carrying out and encouraging measures for the design, development and production of civil aircraft; he has to keep in close touch with the Ministry of Supply, and he is responsible for the Air Corporations and has to see that the right aircraft are present in the right numbers and at the right place for those Corporations. He has also to see that the aircraft which the Corporations adopt are those likely to find a sale in the export markets.

We have to consider the problems of the aircraft industry against the background of the country as a whole. We have lost a great deal of the wealth which we used to possess and so, as we all know, our export trade is more important to us than ever before. In addition, we have an immense armament burden. We have the responsibility to save enough in this country to develop the Empire, and we cannot transfer those savings to the Empire unless we have an equivalent export surplus. Moreover, the vast majority of the electorate have decided that they are not willing to let their standard of living fall below what it is today.

These difficulties might almost seem insuperable. The only way out is so to increase the production of this country that we are able to find what is required for export and for rearmament while maintaining the standard of living of our people. At a superficial glance it might be thought that we had been more or less successful in this, but there are grave deficiencies. We are desperately short of investment and we still have not a proper export surplus. We must not belittle the amount of investment which has gone into industry, because it has been very large; but we are living in an age of such revolutionary progress in the invention of tools and mechanical handling aids and so on, that the need for investment in industry has probably never before been so great as it is today. In any case we have had to neglect investment in many important fields such as roads and railways and even agriculture, among other things. That is the background.

To produce the exports which we need we have had to call in the new industries, and your industry of aircraft production and aircraft operation is one of our new sources of exports. Some people say that we are living in an Air Age. That has been superimposed on or runs alongside the Sea Age. As carriers of people and goods across the oceans we have an unsurpassed reputation, but in this Air Age the advantages on our side are even greater. On the sea the emphasis is on comfort and service, safety being taken for granted, but in the air safety is paramount; you have only to watch the faces of the passengers on taking off and landing to realise that. In the matter of safety we have two immense advantages: we have the enormous reputation built up by the Royal Air Force in the war, and in addition we have the traditional reputation of British workmanship and British maintenance.

A Very Wide Field

We have great opportunities, and we must not miss them. I have had a few figures taken out for me. They are not sufficiently precise for you technical people to be able to trip me up on them. I

am told that in the first half of this year, January to June, the United Kingdom produced 330 civil aircraft and aircraft of all types for export. The U.S.A. in the same period produced nearly 2,300 civil aircraft alone. So far this year, up to the end of November, we have exported about 260 civil aircraft, while in the whole of last year the United States exported some 3,500 civil aircraft. I quote these figures only to show that there is a very wide field into which we can push our way. Can we do it? I consider, *prima facie*, that we ought to be able to beat the Americans in every industry in which an enormous home market for mass production does not favour them, because of the wide difference in wages and so on. That is the approach of the layman; it is you who can say whether we ought or ought not to be able to do it.

The aircraft industry is comparatively new. The old industries have learnt by bitter experience how to sell their goods in the world's markets. They have discovered that you must produce the right sample at the right time to the right man, and then you must be able to quote a price and a delivery date which will suit him and, of course, delivery must be up to the sample.

Those two things are a challenge to production engineering, because we are dealing with an industry which is probably more exacting than any other. Progress is more rapid than in others, and the products of the aircraft industry can be outmoded so much more quickly. To paraphrase the saying of the old American General: "The race is to the swiftest producing the mostest of the latest." Rarely is it possible to get a long production line. We are, in fact, talking in terms of Norman Hartnell and not of Oxford Street.

Importance of the Time Factor

But seven years is a long time—seven years from design to operation. I expect that many of you brighter lads went from your first equation to the differential calculus in that time, but that is the time which it takes to get an aircraft into operation, and it is becoming obsolescent all those seven years. Improvements have to be incorporated as you go along. Any decrease in that time would be absolutely invaluable. Time is always money, and never more so than in the last stages of bringing an aircraft into production and operation.

That is your problem. The designers are the artists of the industry. In Chelsea, the bank balances are owned by those who paint the pictures for which the public are willing to pay, and it is so in this case too. The operators are the public and, therefore, close contact between the designers and the operators is particularly to be sought, and the designer must know what are likely to be the future needs of the industry. Once the designer has got on to something which he thinks is good and which interests the operator, consultation is very desirable, so that the operator can learn about the developments and the designer can learn more about what are likely to be the detailed requirements of the operator.

There should be—it is so easy to say, but so difficult to put into practice—a minimum of modifications on the way through, because they cause delay, and will delay our possible exports. We have here in your industry an example of the eternal problem of whether in the search for perfection we are to lose the cream of the market, and whether something good now or something a little better later is to be our goal. That is fundamental, but simple. There are other points which tend to be overlooked, such as consultation at an early stage with the Air Registration Board, which sometimes saves trouble later, and the need for the proper provision of spares for every modification which any operator may have demanded.

Influence of Cost on Fares

I would add a word about price. I often wonder whether we have heard as much about price in this industry as we ought to hear. How long is a modern passenger aircraft going to last? Nobody really knows. If we take a life of ten years, the cost of that aircraft has to be recovered from passenger fares over that period of ten years. Depending on the type and so on, that means that between 5 and 10 per cent. of every passenger fare has to be set aside for the replacement of the aircraft when its useful life is over, so that any reduction in first cost means that fares can come down.

The old idea that air flight was a means of transportation for the V.I.P., the top business executive, and those who, in spite of the attentions of the Chancellors of the world, always seem to have plenty of money, is dying out. We know that there is a vast new market for air travel, consisting of people who have to pay their own fares out of income, income which is highly taxed in every country in the world. For those people, given a reasonable standard of comfort, it is price which matters. In the final outcome, whether people decide to take a holiday in the Old Country and travel by air will be decided very often by whether the fare is £100 or £150.

Today the front page in the civil air world is held by our glamour girls, the Comets. They may be called the film stars of the air. Lest I should be accused of making innuendos at Hollywood, let me say that my simile is dictated by their beautiful curves, not their speed and, of course, these owe nothing to the pneumatic engineer. But what of the Mrs. Mopps of the air world, the sturdy Dakotas chugging away over the wide-open spaces of the world in South America, Africa or Australia, carrying people about their daily business in countries where railways, as we know them, do not exist at all? It is

(*Concluded on page* 101)

Second Conference on

"PROBLEMS OF AIRCRAFT PRODUCTION"

Southampton, 18th/19th December, 1953

The second Conference on "Problems of Aircraft Production", organised by the Southern Section of the Institution, took place on 18th/19th December, 1953, at the University of Southampton, by kind permission of the Vice-Chancellor.

The Conference was attended by nearly 200 senior executives in the aircraft industry, and was opened by the Right Hon. Lord Hawke, deputising for the Minister of Transport and Civil Aviation, the Right Hon. A. T. Lennox-Boyd, who was detained at the last moment by Parliamentary business.

Following the opening luncheon the programme was as follows:

SESSION I

"THE TREND OF DESIGN"

Speaker: D. KEITH-LUCAS, B.A., M.I.Mech.E., F.R.Ae.S., Chief Designer, Short Brothers & Harland Ltd.

Chairman: G. R. EDWARDS, C.B.E., B.Sc., F.R.Ae.S., Managing Director, Vickers-Armstrongs, Ltd.

SESSION II

"PRODUCTION PROBLEMS ARISING FROM THE TREND OF DESIGN"

Speakers: G. H. DOWTY, M.I.Mech.E., F.R.Ae.S., F.I.Ae.S., Chairman & Managing Director, Dowty Equipment, Ltd. (Owing to Mr. Dowty's sudden illness, this Paper was read by Sir Roy Fedden, M.B.E., D.Sc., F.R.Ae.S.).

S. P. WOODLEY, M.B.E., Superintendent, Supermarine Division, Vickers-Armstrongs, Ltd.

Chairman: W. BROWNING, M.I.Mech.E., F.R.Ae.S., M.I.Prod.E., Director and General Manager, Saunders-Roe, Ltd.

SESSION III

"USER PROBLEMS AFFECTING THE INDUSTRY"

Speakers: B. S. SHENSTONE, M.A.Sc., F.R.Ae.S., A.F.I.Ae.S., Chief Engineer, British European Airways Corporation.

Air Marshal Sir R. Owen Jones, K.B.E., C.B., A.F.C., Controller of Engineering and Equipment, Air Ministry.

Chairman: F. C. COOKE, M.I.Prod.E., President, Southern Section.

Summing-up

Speaker: SIR FREDERICK HANDLEY PAGE, C.B.E., Hon.F.R.Ae.S., Hon.F.I.Ae.S., F.C.G.I., Hon.M.Inst.T., Chairman & Managing Director, Handley Page, Ltd.

Chairman: W. C. PUCKEY, M.I.Prod.E., F.I.I.A., President of the Institution.

A full report of the Conference appears in the following pages.

"THE TREND OF DESIGN"

by D. KEITH-LUCAS, B.A., M.I.Mech.E., F.R.Ae.S.

Mr. D. Keith-Lucas

Mr. Keith-Lucas was educated at Gresham's School, Holt, and Gonville and Caius College, Cambridge. He took an Honours degree in the Mechanical Sciences Tripos in 1933 and then served a post-graduate apprenticeship with Messrs. C. A. Parsons & Co. Ltd., Newcastle-upon-Tyne, and remained with that Company until 1939 working on the design of steam turbines.

In 1940 he joined Messrs. Short Brothers at Rochester and in 1941 was appointed Chief Aerodynamicist. In 1949 he was appointed Chief Designer of the Company which had then become Short Brothers & Harland, Ltd., at Belfast, and in January, 1953, he was appointed to the Board of Directors.

In 1949 he presented a Paper on "The Relative Efficiencies of Large Landplanes and Flying Boats" before the Second Anglo-American Aeronautical Conference in New York, and in 1951 a Paper entitled "The Shape of Wings to Come" before the British Association in Belfast.

AN aircraft designer's business is to design the right aircraft for the job. As the aeronautical sciences develop there are more and more jobs which can usefully be done by aircraft and therefore a wider diversity of aircraft types.

Fifty years ago there was only one job which the aircraft had to do and that was to fly—if it could.

To-day, on the other hand, we have types as diverse as the Beverley and the Comet, the Seamew and the Vulcan. We also have helicopters and guided missiles and may one day have flying saucers, space ships and artificial satellites.

Our subject is, therefore, rather a wide one unless we limit it to aeroplanes with fixed wings, which is what I propose to do.

In low speed aircraft we seem to be reaching some sort of unanimity between designers as was demonstrated by the similarity between the Athena and the Balliol which were designed to the same specification, and likewise the Provost and HPR 2. Figs. 1 and 2 illustrate these aircraft and show that it takes an expert "spotter" to tell them apart.

At the high speed end of the scale we find an equally striking divergence of views (Figs. 3 and 4). No one could mistake a Vulcan for a Victor, which were built to one specification, or a Javelin for a DH 110, which were built to another.

The reason, of course, is that this is new ground and we are feeling our way.

As we increase speeds into the supersonic range we are likely to experiment with a crop of new shapes including deltas with 70 or 80 degrees of sweepback, and straight winged aircraft looking more like guided missiles.

Apart from the outside shape there are other equally important if less obvious changes taking place as a direct result of higher speeds. Knobs and blobs of all sorts have disappeared and the surface finish is

Fig. 1. Boulton Paul "Balliol" and Armstrong Whitworth "Athena"

Fig. 2. Percival " Provost " and Handley Page " HPR.2 "

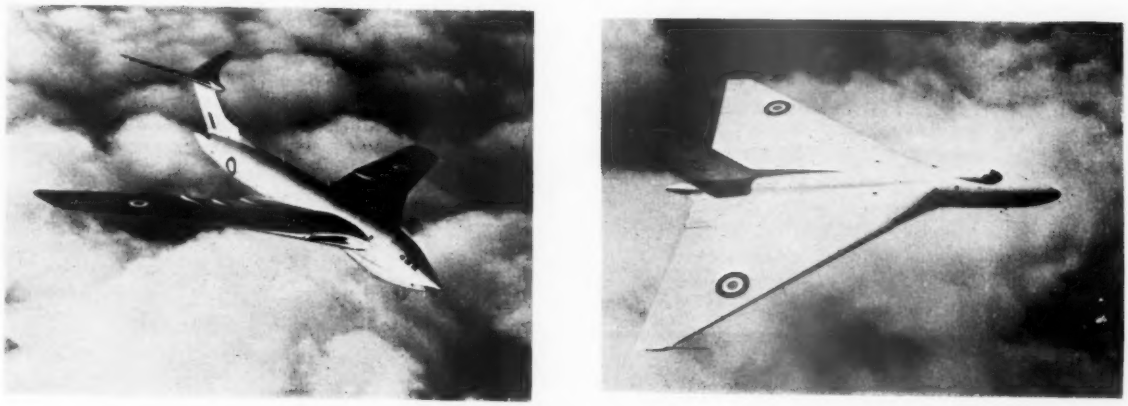


Fig. 3. Handley Page " Victor " and Avro " Vulcan "

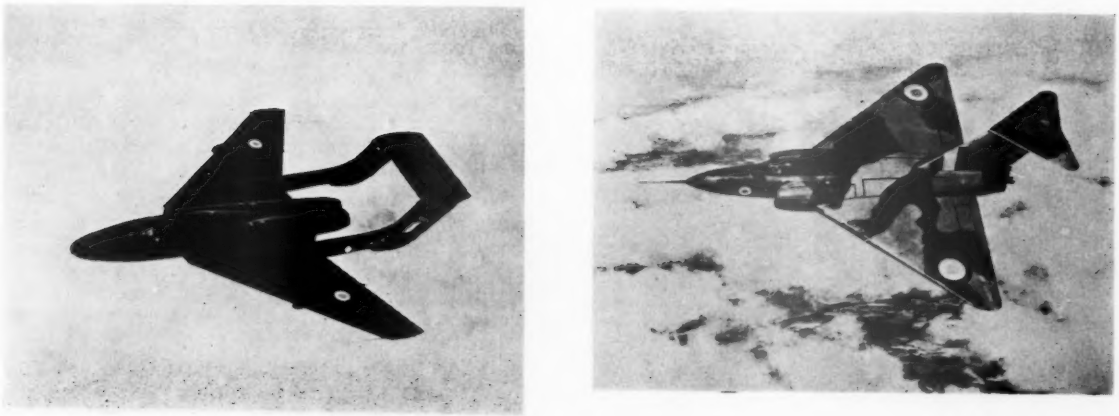


Fig. 4. de Havilland " DH.110 " and Gloster " Javelin "

distinctly better than it used to be—or, should I say, it ought to be if it is not.

If we look inside we find other effects such as an increase in the complication of the electrical and hydraulic services and a very marked increase in density. New materials and new methods of construction are coming into use.

I want to take a look at some of these effects and try to get the measure of them to see whether they are necessary or unnecessary. Can we dodge them or must we accept them with as good a grace as we can manage?

I am taking it for granted that the cause of these developments, namely the quest for higher speeds, is inevitable. Military necessity has called the tune and the civil operators are dancing to it with apparent gusto. There cannot be any serious argument about it; we must progress to higher speeds.

The next step, from the transonic to the supersonic, is going to be a difficult one but we cannot allow ourselves to be frightened by the prospect. We have just got to face the consequences squarely, and that, really, is what we are here to do.

Outside Appearance

The question is often being asked to-day whether the supersonic aircraft of tomorrow will have swept wings or not.

Looking at the drag picture we see that the peak drag, which, on a straight wing, occurs around the speed of sound, is much reduced by making the wing as thin as possible. Sweepback, on the other hand, not only reduces the peak but delays it to higher Mach. Numbers.

If we are designing for speeds just a little above the speed of sound there is an obvious case for using sweepback to delay the drag rise.

But, if we want to fly at a Mach. Number of the order of 2, the amount of sweepback required becomes rather frightening and the alternative of using a straight wing and flying at a speed well above the peak drag becomes quite attractive.

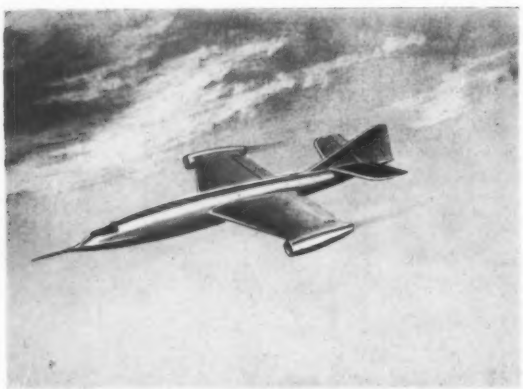


Fig. 5. Artist's impression of a straight winged supersonic aircraft.

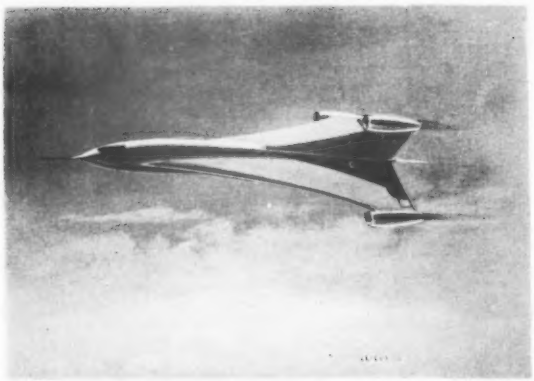


Fig. 6. Artist's impression of a delta winged supersonic aircraft.

We will examine this one first and to focus our ideas we can look at the artist's impression of such an aircraft in Fig. 5.

The wing is extremely thin; its thickness: chord ratio is probably only 3% or 4%. This is necessary not only because of the enormous drag penalty of thicker wings at such high supersonic speeds, but also because it has to fly through the peak drag speed. Other unpleasant results of compressibility such as wing dropping, trim changing and buffeting, reach their maximum at about the same speed as the drag rise and, like the drag rise, are rendered comparatively innocuous only by extreme thinness.

The wing is not much good for storing anything, not even fuel. The engines are therefore shown at the wing tips and the undercarriage will, presumably, have to be in the fuselage, which is not a very nice arrangement. It looks rather like the popular conception of a guided missile.

The alternative with about 80° of sweepback is shown in Fig. 6. It is something like the ultimate in deltas and looks very like a paper dart.

Structurally it appears rather easier than the straight winged counterpart and it is a much better shape for stowing the fuel and undercarriage. The engines are still outside because, if buried in the wing roots, the losses in the long intakes and jet pipes would be unacceptable.

It seems to be quite a practicable proposition; the centre of gravity comes in about the right place and the longitudinal damping should be good although it may be a bit touchy in roll.

We must admit, however, that we do not yet know much about wings of this sort and there may be serious troubles ahead. The nearest we have yet been is on the S.B.5 research aircraft with 60° of sweep (Fig. 7) but we hope later to go to 69° which ought to provide useful data even though the aircraft is only capable of low speeds.

For long range aircraft it is essential that the lift: drag ratio should be as high as possible, which can only be achieved by cruising at a reasonably large lift coefficient.

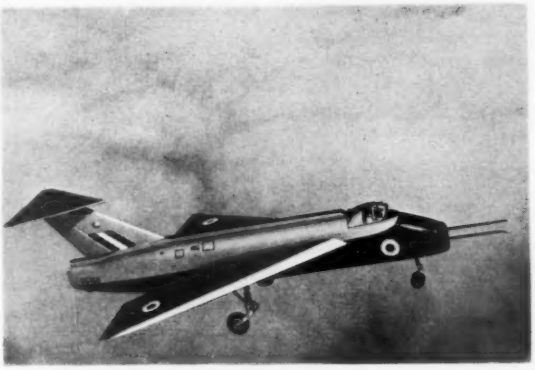


Fig. 7. Short "S.B.5" with 60 degrees of sweep

Unfortunately the highly swept delta platform has a low slope to its lift curve so a large lift coefficient means a large incidence, and a large incidence means a large induced drag because, at supersonic speeds, the lift vector is normal to the plane of the wing.

This is probably the strongest argument against the delta but I still confess a certain partiality for it, mainly on the grounds of useful space in the wing.

Inside Secrets

The problem of stowage capacity inside the aircraft is embarrassing us already but a glimpse into the future shows that it is likely to become even more acute.

As speeds increase it is certain that the designer will strive even harder to reduce the available volume to a minimum because the penalty which has to be paid for unnecessary frontal area becomes so colossal.

What makes it much worse is that the faster we go, the more fuel and the more engine power we need. The volume of the fuel and engines must therefore tend to increase.

Add to this the fact that every new aircraft carries more secret electronic equipment, more electrics, more gadgetry, and we have a sizable problem in a very small nutshell. Every production engineer knows what this means, particularly in the final assembly stages when only one man at a time can work inside the fuselage and he has to be selected for his figure rather than his skill. I am afraid it is one of the things which we cannot hope to avoid although good design may greatly ease the problem of access.

By comparison it is interesting to look back at the old days of, say, the Sunderland flying boat. If the

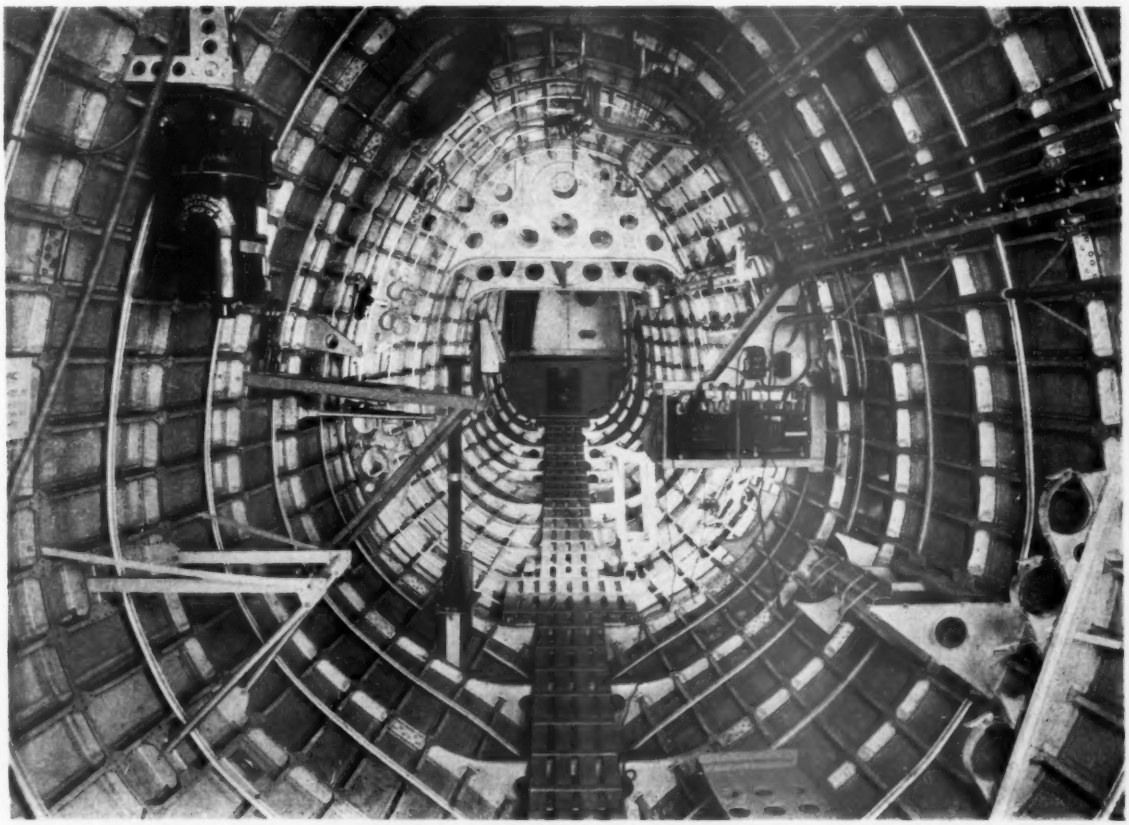


Fig. 8. Interior of Sunderland Flying Boat

Fig. 9 Boeing "B.47" with engines and fuel tanks slung outside

customer wanted to add a bit of equipment, there was always room for it, as you can see in Fig. 8. This may be one reason why the aircraft started life at 44,000 lb. and is now flying at 60,000 lb. or, in its developed form as a Solent, at 80,000 lb. The Lancaster, Stirling and Halifax were nearly as spacious.

Today we cannot afford to carry all that space about with us and for long range operations we have to sling part of the fuel outside in wing tip or belly tanks. On the other side of the Atlantic we find examples such as the B.47 where both the fuel and the engines are slung outside (Fig. 9).

Tomorrow we can no longer be content with slinging things outside, we will have to sling them out. I would like to start with the undercarriage but after that it becomes rather a difficult choice. Rationalisation and simplification of the equipment is probably the most fruitful field but the problem deserves very careful thought.

Integral Construction

One aspect of the stowage problem is that the structural designer must assume the responsibility of producing not only the lightest structure, but the one which gives the maximum of usable space inside the wing and fuselage.

High speeds and thin wings are already setting a very severe problem and consequently there are a number of new developments in structural design.

I would like to choose one or two of these for closer examination. The first one I shall take is "integral construction" where the skin and stringers are machined from a single slab.

Fig. 10 shows a plank in the course of machining. It was built as an alternative to the more conventional skin-and-stringer sandwich construction of the S.B.5 research aircraft, with which it is compared in Fig. 11.

Fig. 10. Integral plank in course of machining at Short Brothers & Harland

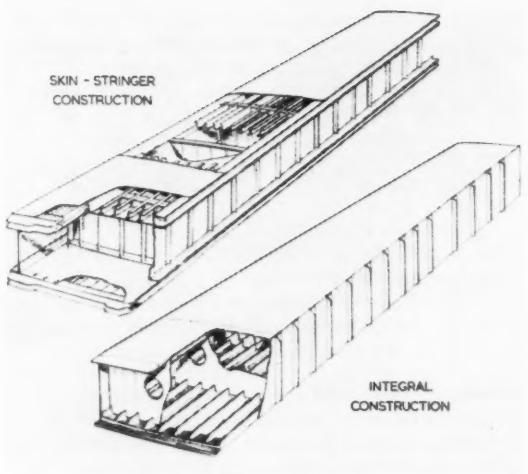


Fig. 11. Integral construction in comparison with conventional

The integral construction gave a saving of 25% on the weight of the component and, in production, the cost is estimated to be about 39% below the original.

The weight saving is due mostly to the facts that the skin and stringers are uniformly tapered and no weight is thrown away on joints.

A very real advantage is that the surface finish of such a wing is greatly superior to the conventional.

Another advantage which I have heard claimed for integral construction is that if the all-up weight of the aircraft increases, the structure can be increased to suit merely by altering the depth of machine cuts and without appreciable redesign.

It also provides just the right sort of construction for integral fuel tanks and so saves further weight.

The Americans are using integral construction more and more. It is right out of the experimental stage and into production. For example, Lockheeds have produced over 200 of their large wing panels, 4 ft. wide by 30 ft. long, for the Super-Constellation.

It seems logical that the technique will soon spread to other parts of the aircraft structure including wing ribs, spar webs, fuselage panels and possibly even cabin flooring.

In spite of all this there are designers, including many in America, who do not believe in integral construction. They say "Our job is to manufacture aircraft—not chips" or "It is a natural law that hogging out of the solid is a pig of a business".

I suggest that most of those who condemn it have not tried it, like those who condemn modern art without having seen any. One American firm which does more "sculptured machining" than most, claims that the cost of production including machining, materials and overheads, is $\$1\frac{2}{3}$ per lb. against $6 or $7 per lb. by previous fabricating methods. These figures are striking whatever the factor of enthusiasm which we may choose to apply.

Even so we must see whether there is not a still cheaper way of doing the same thing by extruding, forging, rolling or even welding.

The most serious objection to machining from the solid is, in my opinion, that it is going to be difficult to do in the highest grade materials without running into cracking and distortion problems. It is also doubtful whether we can get the best properties out of material in slab form.

The logical development in integral construction is to delete the ribs and substitute multiple webs running spanwise along the wing. There will be a nasty problem for the production engineers to solve as the accessibility for assembly will be decidedly restricted.

Metal Bonding and Sandwich Construction

While integral construction has come to challenge the more conventional skin-and-stringer combination, the older methods have not stood still.

Many designers are turning to redux bonding in preference to rivets for attaching the stringers. The most important advantage is probably that it gives better fatigue strength, but it also has advantages in better surface finish and in the continuous attachment between the skin and stringers which prevents inter-rivet buckling and gives greater compressive strength.

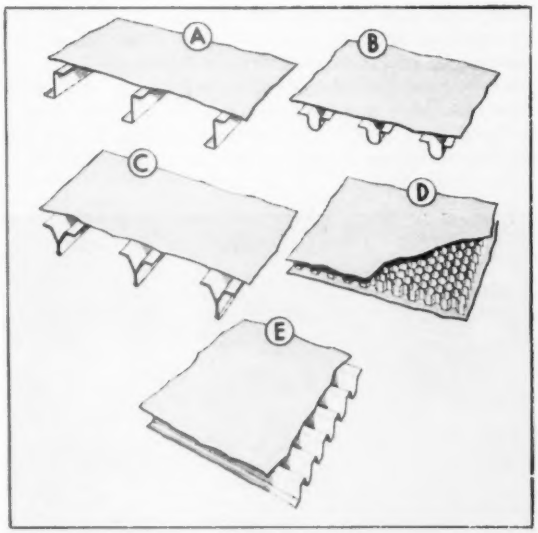


Fig. 12. Stringer and sandwich construction:
(a) "Z" stringers, (b) Top Hat stringers, (c) "Y" stringers, (d) Metal honeycomb sandwich, (e) Corrugated inner skin.

Closed section stringers, such as top hat or Y sections, are more stable than open sections such as the familiar Z. In the past there has been a reluctance to use them because of the danger of undetected corrosion occuring inside the stringers and because of the extra riveting involved.

With redux bonding the closed sections become more attractive and are, in fact, used extensively on the Comet.

Extruded rather than formed stringers are also finding favour mainly because of the good longitudinal properties of the material and partly because the fillet in the corner helps to resist instability. The extruded Y section is probably the most efficient section known, but a simple angle has the advantage that it can be tapered by machining, so reproducing one of the advantages of integral construction.

The use of metal bonding opens up a wide field of possible sandwich constructions. The aluminium honeycomb looks to me to be much better than foam or balsa as the filling for such sandwiches, and I think we will see much more of it in the future (Fig. 12).

It can be used in two ways, either as a double-skin sandwich replacing the conventional skin-and-stringer combination or, for very thin components, as a complete filler between the outside skins, in which case it also replaces the ribs.

In either way it is mainly applicable to components in which the end loads are of fairly low intensity. This includes the primary structure of light aircraft and, on high performance types, might include fuselages and tail surfaces and also the wings of delta aircraft. For V wings, with their higher aspect ratio and less taper, the end loads are of much higher intensity and integral construction is more suitable.

As a complete filler it might well be applicable to control surfaces and tabs, bomb doors and helicopter blades. It gives an excellent surface finish and can be made in large pieces with very little penalty in the weight of joints. But even a sandwich is not all jam; one of the objections to its use is that it is costly in space, particularly when we are considering integral fuel tanks. On the other hand, this is no argument against its use for control surfaces or bomb doors as the internal space is scarcely usable anyway.

One other limitation is that on very thin wings it is inefficient because it brings the material too near to the neutral axis of the wing. On thin wings of this sort the end loading is likely to be high so sandwich construction is unsuitable in any case.

My guess is that we will see it used extensively in the future and not only for secondary structures nor only on light aircraft.

Fig. 13 shows another application of redux bonding. where a corrugated inner skin with the corrugations running chordwise is bonded to a smooth outer skin. This type of construction is used in the leading edges of the Britannia wings and shows some promise for the primary wing structure of light aircraft.

Choice of Materials

We cannot very well discuss structures without discussing the materials from which they are built.

For many years the metallurgists have been steadily improving the strength properties of the aluminium alloys. These new alloys have been a great help to the structural designer but it begins to look as if we are nearing the end of what we can expect from this source.

Tensile strength is not the only criterion of a good structural material, indeed I have heard the exaggeration that it is the last thing in which the designer is interested. Without going as far as that we can see the reasons which prompted the thought.

Much of the structure of modern high speed aircraft is being designed on considerations of stiffness rather than strength and, when that is so, there is no point in using the very high strength materials.

This is really a confession of weakness because it means that we are not getting the best out of our materials. The logical solution is to allow reduced stiffnesses by making the aero-elastic distortions work for us instead of against, and to overcome flutter by subtlety instead of inflexibility. This is the philosophy behind the aero-isoclinic wing which deserves a lot more attention than it has yet received. The Short Sherpa, shown in Fig. 14, is the first aircraft ever to be fitted with such a wing.

Fig. 13. Interior of wing with corrugated inner skin

Fig. 14. Short " Sherpa " with aero-isoclinic wing

But, to return to the materials, other limitations to the use of the high property aluminium alloys are their poor crossgrain properties and low elongation.

There is also the suspicion that they are not too good in fatigue. We need to know a lot more about fatigue, but we do know that with high grade materials it is forcing us to be much more meticulous about surface finish of machined parts and about the avoidance of scratches, particularly on wing sheeting.

It is another of the limitations of the high property aluminium alloys that their resistance to fatigue, particularly when built into a structure, does not increase in proportion to their ultimate or proof stress.

With steels, on the other hand, the ratio of fatigue to ultimate strength is more nearly constant, which may be one reason why the Americans are showing interest in high tensile steels. They are talking of ultimate tensile strengths of 280,000 lb./sq. inch as opposed to about 80,000 lb./sq. inch maximum for aluminium alloys.

Lower grade steels are not very attractive for aircraft structures because of their low strength-weight ratio and where used for nacelle structures, fireproof bulkheads, etc., they are likely to be ousted before long by titanium.

Titanium

Titanium and its alloys hold great promise for the future when we get to understand them better and can get the price down to something more reasonable.

In the first place, titanium is a useful structural material. It gets its name from strength which is likened to that of the giant Titans. Let us hope that the resemblance ends there and that it will not also prove to be a myth. I hardly think it will.

In the second place, titanium maintains its properties well at elevated temperatures.

It is interesting to look back only a few years and see how worried we were by the effects of low temperatures on jet aircraft cruising in the stratosphere. We were deeply concerned about the notch-sensitivity of certain steels at –70° or –80°C. and about transparencies which became brittle and crazed very easily.

But blow hot, blow cold, we are now equally worried by the high temperatures which will be generated by supersonic flight. This is where titanium offers its greatest promise.

We must make the effort to get to know its little ways and to understand it properly. Its properties are not yet sufficiently consistent for us to put all our faith in it.

Materials can be very human in their characteristics. The strongest personalities are not very tractable or ductile, but will shoulder heavy responsibilities and will never yield until they bust. The milder brethren are more reliable and easier to work with but they are generally the second-raters and you need more of them to do the work.

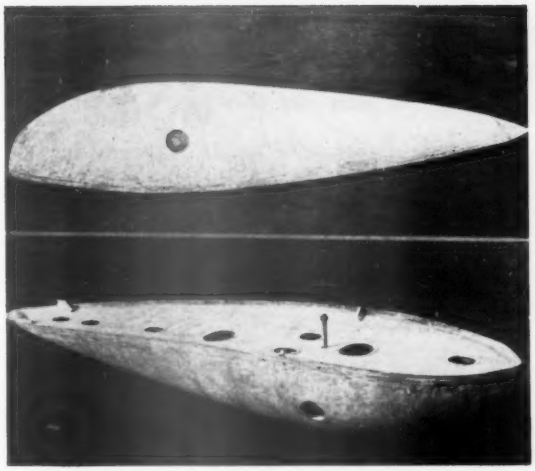


Fig. 15. Drop tank in resin bonded glass laminate

You can't run a first-rate business on second-rate men any more than you can build a first-rate aircraft of second-rate materials.

I like to look on materials this way. It may not be very scientific but it helps me to be sympathetic towards them and to understand and forgive their faults. Titanium, like the high property aluminium alloys, is a strong character. Only by patience will we get it to be wholly co-operative.

Plastics

Some materials take a great deal of understanding and chief among them are the reinforced plastics such as Durestos and the resin-bonded glass laminates.

Fig. 15 shows a drop tank for a high speed aircraft. The tank is built entirely of glass laminate.

The glass fabric gives excellent tensile properties but is poor in shear and not too good in compression. I would go as far as to say that it is fundamentally not a good structural material.

Its advantage lies mainly in the fact that it can be moulded and therefore, if we understand it well enough, we can put the strength just where and how we want it. We can then produce structures which are comparable and, in some cases, lighter than the corresponding structures in light alloys.

It is an excellent example of the weight saving which comes from deleting joints.

Joints

Whatever the material we are using we can save a lot of weight if we can eliminate joints. There are always plenty of people demanding more joints —for production breakdowns into sub-assemblies, to permit the job to be done on smaller machine tools, to facilitate transport or to allow the aircraft to pass through the dockyard gates.

Joints cost a lot in weight and must be kept to a minimum. We are beginning with the use of large forgings, integral construction and plastic mouldings but we must go further.

In this country we seldom use extruded stringers or spars longer than 30 ft. In America 40 ft. is common and 80 ft. is being used. The Americans have also explored the possibility of casting the wings in magnesium alloy—all with the same object in view.

Of all the recognisable trends in design this one towards fewer joints, and therefore towards larger pieces, is one of the most clearly defined.

It is setting a major economic problem of how far we can afford to go with the provision of larger forging presses and machining capacity capable of producing larger pieces.

Complexity

Money is one of the controlling factors in aircraft design and there is no more vexed question than that set by the ever increasing cost and complexity of modern types. As a measure of the problem I would like to quote a few figures on electrics.

A certain twin-engined military aircraft recently withdrawn from service underwent the following changes in eight years:

Number of individual cables increased by	360%
Number of items of equipment	140%
Power consumption	225%
Weight of equipment	175%

or in the civil aircraft field:

Medium flying boat transport ten years ago (Sandringham type)	6 kW.
Medium transport today (Britannia type)	100 to 150 kW.

The subject deserves a whole lecture to itself with all that it means in cost, performance, weight, production, maintenance and crew training. At a rough assessment, one extra pound of equipment to-day means ten pounds on the all-up weight of the aircraft. It is no wonder that many designers are struggling to get back to Bill Stout's famous slogan of "simplicate and add more lightness". What, after all, is the use of an aircraft on which the daily inspection takes 25 hours?

How I wish I could stand here and say honestly that this complication is unnecessary. It just is not as simple as that. We must go back to where we came in. "A designer's business is to design the right aircraft for the job".

If added complication allows one aircraft to do the job of several or to do a job that cannot be done without that complication—then it is worth it.

Fig. 16. Short "Seamew"

But there is the other side to the penny. Too much complication in a fighter makes it too large and heavy and impairs its performance. It also means that it costs more and we can't afford to have enough of them. What again is the use of the perfect aircraft if we have so few of them that we lack the vital one in the right place to meet the enemy when he attacks?

This last argument applies with particular force to anti-submarine aircraft and is the philosophy behind the Seamew.

Fig. 16 shows that it is not a very beautiful aircraft, it doesn't look very modern and its undercarriage doesn't even retract. But I make no apology. It is designed to be the right aircraft for the job and the further we progress, the more strange jobs we will find for aircraft to do, and the more strange aircraft we will design to do them.

That is the best of this game. There is nothing static in aircraft. We are still in the exploratory stage, thinking up new ideas and chasing after them.

The production man and the designer must chase together, neither leaving the other one behind, for the simple reason that neither is any good without the other.

The trend of structural design is towards fewer parts with fewer joints. It is now up to the production men to put it into practice. Let us simplify the structures even if everything else is getting more complicated. And, whilst we are at it, let us get the very best joint between Design and Production.

Acknowledgments

I wish to acknowledge my indebtedness to Mr. C. H. R. Griggs for a number of the illustrations and Mr. K. L. C. Legg for his valuable criticisms.

DISCUSSION—SESSION I

Chairman: G. R. EDWARDS, C.B.E., B.Sc., F.R.Ae.S.,

Managing Director, Vickers-Armstrongs, Ltd.

Professor E. J. Richards (*Head of the Department of Aeronautical Engineering, University of Southampton*) said he had been asked to open the discussion for one reason only, and that was to give him the opportunity of welcoming all those attending the Conference to the University of Southampton and to wish the Conference every success. As a University lecturer, he would also like to congratulate Mr. Keith-Lucas most sincerely on his presentation of the Paper.

He agreed with all the sentiments expressed in the Paper and, in particular, with the desirability of trying to make things out of one piece rather than by putting a lot of pieces together. Machining out of the solid was something which was in its infancy in this country, but he thought that it was a very sensible idea and was sure that the figures of cost which had been given were correct and would be proved to be so in time to come.

It would be interesting to know whether Mr. Keith-Lucas was prepared to go further in his prediction of the cutting out of numbers of small pieces. He did not mention power operation, but it seemed probable that production engineers would have more trouble with the small mechanical bits involved than with the assembly of large items. What did he feel was going to be the trend there? Now that more was known about supersonic aerodynamics, were they going to take the coward's way out, as they had up to now, and go to pure power, or would they turn to a semi-manual system of some sort, thereby eliminating many of the bits? This would be much cheaper in first cost and need less maintenance than auto-pilots and that sort of thing. Must power operation be adopted *in toto* simply because the job was too hard otherwise?

It would also be interesting to know whether, in view of the enormous complication of wiring, printed wiring could be used, and to what extent its use had gone.

Mr. Keith-Lucas wanted to throw out the fuel, but Professor Richards would like to take up that question with him. Tanks, after all, could be made of any shape, and therefore could be fitted in to the shape which happened to be available, whereas engines could not; if, therefore, from the point of view of space it was necessary to throw out either the engine or the tank, which should go? There would appear to be a case for putting the engine outside and keeping the tank inside. He thought that the most important feature of the supersonic aeroplanes of the future would undoubtedly be spaceworthiness and he wondered whether, on the question of trying to develop the optimum shape, either a highly-swept-back or straight-wing aeroplane, the philosophy of spaceworthiness had got into the drawing offices yet.

His last point was also concerned with throwing things away. He would like to see the canopy thrown away and telescopic vision developed. That might well come about in future, and it would be interesting to know what practical designers felt about it.

Mr. Keith-Lucas, on the question of power controls and the number of pieces involved, said he did not claim to be an expert on this subject, and had funked the issue by using another form of power control, namely the aerodynamic servo tabs. So long as they were usable he would go on using them, but he wished that he knew just where the borderline came. On principle he did not like the idea of brute force, but preferred ju jitsu. If they could get the air to work for them, they would not need quite so much brute force. He thought that power controls were inevitable at very high speeds, but it should be possible to reduce the amount of power required.

He believed that printed wiring was definitely coming in all sorts of different ways in the components, but whether it would come in the near future in the aircraft as a whole he did not know.

He agreed with Professor Richards that there was often a good case for throwing out the engine, but the real reason for that was that by putting it outside it was possible to get a very efficient intake and a very efficient exhaust; the intake was short and the exhaust pipe was short. If it were possible to get the same situation in the wing it might be worth having the engine in the wing, but if the intake duct and the jet pipe were many yards long, by throwing out the engine, room was made for a great deal more fuel.

There was no simple answer, and everything had to be regarded on its merits. They should look for things to throw right out of the aircraft, and he liked the suggestion that the canopy should go. On many occasions he had wondered whether it would not be possible to throw out the pilot with it, because pilots were a great nuisance. They spoilt the symmetry of the structure, they demanded a good view and they wanted all sorts of bits of equipment especially for themselves. So far, however, it had not been possible to find anything else which could think, and so they had to put up with the pilot. He sometimes wondered whether, that being so, they could not save a little by at least breeding smaller pilots. Chief test pilots, for example, were a most extraordinary band of men, some tall and thin, some short and fat, but not one seemed to be small, and he wondered why.

The question of "spaceworthiness", as Professor Richards termed it, seemed to be becoming understood and accepted. A few years ago the one thing that designers bothered about was the weight of each component which had to be put in, but today the space occupied was equally important, if not more so, because a large piece of equipment meant that the whole aircraft had to be bigger, with more structure weight, more fuel weight and possibly even more engine weight.

Mr. P. V. Brown (*Directorate of Aircraft Production Development*) said that the case for integral construction for very thin wings on supersonic fighters was very clear, and in fact there seemed little else possible. He spoke with no inside information, but he wondered whether there was not a general feeling that the guided weapon would in the near future do away with the need for this type of aircraft for attack and defence, thus eliminating the problem entirely. This would leave the larger civil and transport types on which to concentrate efforts. There, with larger and thicker wings, was the case for integral construction so strong.

Should not engineers be continually trying to increase the material utilisation of their manufacturing processes? The use of tapered rolled wing skins, to which could be bonded sheet metal stringers also having tapered gauge thickness, would approach closely the efficiency of a similar

panel with tapered skins and stringers integrally machined. Rolling mills could be made to produce these tapered sheets and were available on the Continent.

Mr. Keith-Lucas mentioned that tensile strength was not necessarily the first property to be required of the material, and it would be interesting to know why, in his view, greater use was not made of magnesium-zirconium alloys in this country. Due to their low specific gravity, skin thickness could be nearly twice that used on aluminium alloys, so obtaining increased stiffness for the same weight. Were people worried about the fatigue properties of these materials, or about the manufacturing problems, or was it corrosion bonding, riveting, or just the manipulation in the workshop? The Americans were using these sheet materials to an increasing degree for all forms of structures, including skins.

With regard to the elimination of structural joints, the advantage which these could afford had been shown on many civil types of aircraft, because they made it possible to remove and scrap major components before fatigue failure occurred. Mr. Brown wondered whether, from the designer's point of view, the elimination of these joints would help to eliminate fatigue failure? Might they not increase the problems, if too much rigidity was built into the structure? Moreover, with the elimination of joints the problems of maintenance, replacement and spares would surely be made more difficult.

Mr. Keith-Lucas, dealing with the question of whether integral construction offered as much advantage with the larger and thicker wing, said that it was not a question of the size or thickness of the wing but primarily a matter of the intensity of end loading per foot of chord; he did not mean wing chord, but the part of the chord in which the structure could be placed. With a high aspect ratio and a thick wing it was possible to get up to very high intensities of end loading. The Super-Constellation was a very good case in point of a relatively thick wing and a high aspect ratio, where great advantage had been found in integral construction. He did not agree, moreover, with the assumption that civil aircraft would have these larger, thicker wings; he did not think that that was necessarily correct. After all, the wing of the Comet was not very thick, and it was probable that in time to come there would be civil aircraft which were faster than the Comet and with thinner wings.

He did not know the answer to the question of the magnesium-zirconium alloys, and he would be very interested to hear the views of others on that.

Finally, on the question of fatigue failures of large components, as compared with smaller ones where individual pieces could be replaced, there was a profound difference between fatigue resistance of a specimen in a fatigue testing machine and the fatigue resistance of that same material when built into a structure. Just what caused those differences was not, he thought, fully understood, but he felt sure that with larger individual pieces and fewer joints they would be getting nearer to the ideal of the test specimen and further away from the built-up structure, and it would stand up better to fatigue. He agreed with what had been said about spares, but did not think that one should design so as to make every little bit detachable and replaceable. It might be necessary to do some patching if a piece was injured, but why put in the penalty for that patching in the original design?

Mr. F. E. Jarlett (*Student, College of Aeronautics, Cranfield*), whilst appreciating the fact that the building of fighter aircraft occupied only a section of the aircraft industry, said that the problems encountered on the fighters of today showed themselves to a greater or lesser extent in the bombers and transports of tomorrow. That had been proved to be true for such things as cockpit pressurisation and cooling, wing sweep to delay the onset of compressibility drag rise, irreversible controls and so on. Of the problems being faced today, kinetic heating would undoubtedly fall into this category.

Most present-day fighters were capable of speeds in the range of 600 to 700 knots, twice that of the front-line fighters of the 1940 era. Aircraft such as the Douglas X3, designed to reach $M = 3$ and a height of 200,000 to 300,000 feet—a performance which might well be realised should the aircraft be suitably re-engined—suggested that a fighter ten years hence would be capable of such speeds and altitudes as a matter of course.

The rise above normal room temperature at the stagnation point on an aircraft flying at $M = 3$ was 340°C. in the stratosphere, or 535°C. at sea level. Looking at the properties of orthodox materials at these temperatures, aluminium and magnesium alloys were beginning to go very soggy, and pilots would not like to see their leading edges wilting in the heat. Titanium at 350°C. had lost half its proof strength and ultimate strength and at 500°C. was quite useless as a structural material, at least on present-day figures, although a titanium alloy might very well be developed which would stand up to these temperatures. The only common material capable of operating in such heat was alloy steel, which, incidentally, had good creep properties.

Future wing sections, as Mr. Keith-Lucas had said, would probably have thickness/chord ratios of between 3 and 4 per cent., and for such ratios the torsional stiffness of the wing would dictate to a large degree the type of wing structure adopted. It would demand above all a thick skin to provide an efficient torsion shell and to avoid undesirable tendencies towards aileron reversal, wing divergence and flutter.

Calculations on an unswept wing of 4 per cent. thickness for a hypothetical type capable of $M = 2$ at 40,000 feet had shown that, to meet an adequate torsional stiffness, a steel wing was lighter than an equivalent aluminium alloy wing by some 20 per cent. When the end load induced in the skin by the bending moment was considered as the criterion, a wing of stainless steel DTD166 was found to be only 3 per cent. heavier than a wing of DTD687, a penalty enforced on the aluminium alloy by the reduction in its proof stress at the elevated temperature. Further, higher grade steels, DTD138 and DTD189, would produce a wing about 10 per cent. lighter than one made from DTD687. Another advantage of the steel wing was that greater depth was available for burying control attachments and mountings.

The solution of this problem in a certain high-speed research aircraft had fully justified the adage that there was nothing new under the sun. After all, the Wright Brothers used external control mountings. Was it advisable, therefore, to ignore the potentialities of steel as a major aircraft structural material? Its many qualities would seem to commend its wide use at the high speeds of the near future.

Mr. Keith-Lucas said that that was a most interesting contribution. He agreed that steel had to be given very serious consideration. Mr. Jarlett had chosen certain conditions, and for those conditions had compared a particular aluminium alloy with a particular steel. It would be interesting to see what the penalty in speed would be if one built a very much lighter aluminium alloy structure and limited the speed to what the structure would take. It was possible that a great deal of weight would be added for a very small speed increase. Further, if it were necessary to meet that particular specification, or any other, it was right to start with the aluminium alloys, which were known, and then take the other materials which were known and see how they compared. He thought that that was the right process in every design, to look at aluminium alloy and steel and titanium, the best available at the time, and see which won. Mr. Jarlett might be right; it might be the steel.

Mr. R. E. Mills (*Senior Designer, The Bristol Aeroplane Co., Ltd.*) said that in Mr. Keith-Lucas's interesting Paper he could find no reference to a trend of design towards detail standardisation. He had heard it said that the aircraft industry paid lip service to standardisation. He did

not entirely agree, but he thought that there were many things which could be done but which were not done, and he would like to make a plea in that respect. Standardisation in many forms represented a highly developed article by its use in the past and by the demand for standardisation, and he felt that designers and production engineers, therefore, should be very pleased to use these things.

He wished also to refer to an old hobby-horse of his, something which was talked about a great deal without much being done about it. In the last paragraph of the Paper reference was made to the need for getting "the very best joint between Design and Production". He had made the point before, and made no apology for making it again, that there was need for production designers, a new type of person, perhaps, but one who could really help in this field. He had made the suggestion before, and people said it was an excellent idea, but nobody did anything about it. What did Mr. Keith-Lucas think about that?

Mr. Keith-Lucas, taking the second point first, said that his first reaction to it was that, as in the old-established heavier engineering industries, they should do their best to see that every single draughtsman in their design offices had served a proper apprenticeship in the shops. (*Applause.*) Often nowadays an apprenticeship was not served altogether in the shops, because at least two days a week were spent on academic studies, and then, if he did reasonably well at those, at the end of three years a boy might go straight into the drawing office, while still termed an apprentice. That was not giving budding designers a sound enough training in the shops.

It was true that he had not mentioned standardisation, but that was because he was trying to think of those things which were changing rather than of those which were not. Standardisation was essentially the enemy of progress. It was necessary in some cases, but it prevented new things happening; it consolidated the position which had been reached. He did not think that it had a proper place in his Paper, but he did think that it had a proper place in their thinking from day to day.

Mr. B. P. Laight (*Chief Designer, Blackburn and General Aircraft, Ltd.*) said that Mr. Mills had taken the discussion back in a direction in which he would suggest it should go, namely in the direction of production rather than one appropriate to pure design. Mr. Laight proposed to deal, therefore, with the way in which production made its impact on the designer. He would like to ask in the first place what was really meant by aircraft production, because in the aircraft industry they had manufacture of two kinds: they sometimes made a one-off aeroplane, and at other times they had the good fortune to make large numbers. He would like to ask the production engineers how they would suggest that the discussion should distinguish between those two parts of aircraft production work. There were many decisions to be taken both in the drawing office and on the shop floor as to how to deal with an aeroplane, according to whether there was the possibility of a large number to follow or not.

When they did get on with production, it seemed to him that production engineers would like to be quite sure what they were producing. They would, he imagined, like to do production in what he might call the motor-car sense, and be able to feel that they knew, as soon as they had to produce something, exactly what it was.

Inevitably, however, there were changes in the design, of various sorts and occurring at all times during production. Did production engineers have trouble with these changes and find themselves not able to make things because they were not sure exactly what had to be made?

On Mr. Mills' last point, Mr. Laight did not think that a special production designer was wanted. He agreed with Mr. Keith-Lucas that a designer should really make sure that his staff knew how to design for production. On his previous point, he was not sure that one always did know what the correct design for production should be, because one might not know how many aircraft were to be produced.

Mr. L. W. Rosenthal, (*Co-ordinating Engineer, Saunders-Roe, Limited*), said that from the design aspect, it was interesting to come to a production engineers' Conference and hear such eminent people as Mr. Keith-Lucas and Professor Richards discussing which items to put outside an aeroplane.

A few years ago, designers were decrying the aeroplane which looked like a Christmas tree and had since spent a great deal of time trying to put things inside, but here they were listening to a discussion on which items to put outside.

Lord Hawke had said that it took seven years to get an aircraft into service. Had a stage been reached of "the higher the fewer", where if aircraft were to go at higher speeds or to higher altitudes there would be fewer of them? It should surely be the purpose of the Conference to discuss how to get new aeroplanes into service in a shorter time. The problem of design made production much more difficult, not only in the shops but also in the drawing office, where work took much longer; for example, wings were being designed to be so thin that it was almost impossible to get in the controls, etc., in the drawing office, let alone in the shops.

The integral construction story reminded him of the snake that first crushed its prey, then swallowed it and when all had been done, proceeded to digest it. He felt that this machining from the solid was rather like that. It was one way of doing a most difficult job, but was it sound engineering? It was attractive from the design point of view, because one could draw what one liked and then leave it to somebody else to find out how to make it. Mr. Keith-Lucas had given figures to show that it might be cheaper in cost per pound to machine from the solid than to fabricate with rivets and pieces of plate, but that was not the ultimate answer, because in war-time the cost had to be reckoned in total man-hours per unit. If expensive machinery had to be built to do the work it would be necessary to include, in addition, the man-hour potential absorbed in building the machines, and with the rate of output required of the aircraft industry under war-time conditions, that was a fundamental point.

Mr. Keith-Lucas had asked for fewer joints for efficiency of design, but might have asked for more joints to facilitate assembly. It was becoming almost impossible to do any rapid assembly work on small aeroplanes because access was only available for one man at a time. It might be necessary for rapid production to manufacture the aircraft in small components, fit the services and then complete the final assembly.

Mr. Keith-Lucas's comparison between the electrics on the Britannia and the Sandringham did not seem to be altogether fair, because the Sandringham had a hydraulic system and a fixed undercarriage (i.e. floats), but the Britannia was, he believed, an electric aeroplane.

On the question of saving weight and space, the two things appeared to be synonymous, because if one saved weight one would save space, and *vice versa.* The effect on the equipment industry had to be considered and as aircraft designers were continually pressing for smaller and more efficient equipment, much more attention might be given this problem.

Mr. Keith-Lucas remarked that he learnt for the first time that the Sandringham had a fixed undercarriage.

It was very difficult, he said, to compile the number of man-hours spent on machining. He had been trying to understand this and to get people to give him figures which would show what he expected, but they always showed the reverse. For example, it was obvious to the most casual observer that an aircraft such as the Canberra had a great deal more machining in it than an older aircraft such as the Sturgeon, and he had tried to obtain figures of the percentage of the total spent on machining. He found that the figure was considerably lower on the Canberra than on the Sturgeon. What had defeated him was the vast improvement which had been made in the method of machining, and the fact that larger numbers were being dealt with. He had the feeling that although when one went into a factory

to-day and saw vast banks of machine tools one felt that this must represent a large proportion of the total effort of the company, in fact the turnover in that machine shop was so rapid that the time spent on machining was far less than might be imagined. That was the only moral which he could draw from it.

Air Commodore G. Silyn Roberts (*Director (R.A.F.) Military Aircraft Research and Development, Ministry of Supply*) apologised if he were drawing a large red herring across the discussion, but said that the answer to the question which he wished to ask, if there was one, would be of considerable interest to him. He had noticed that in recent years it had been customary to order one or two prototype aircraft, flying them and developing them with the usual aches and pains and then, at a certain stage after the aircraft's first flight, and sometimes before it had flown, the decision was made to go into large scale production. From then on he had noticed the course had been anything but smooth; the designers wanted to make changes which were difficult to get into the production line and early in the life of the aeroplane there were numerous modifications required on a large number of aircraft, some of them expensive.

He wondered what the Conference would think of the idea of ordering the necessary number of prototypes for the designers to start off the development, and then placing a small production order for a number of aircraft which would be covered by a specification defining in full what was finally required, but with a note in the specification to the effect that generous concessions would be given on some of the early aircraft, and perhaps on all of them except the last, the aim being to end up with an aeroplane coming off some stage of the pre-production line which was a really good production job, with which it would be possible to go ahead with the main production with confidence and few modifications.

Mr. H. H. Wilson, (*Service Manager, Sir W. G. Armstrong Whitworth Aircraft, Ltd.*), reverting to Mr. P. V. Brown's question of why greater use was not made in this country of magnesium-zirconium alloys, particularly in view of the extensive use made of magnesium alloy sheet in the U.S.A., said that the short answer was that use was being made of them, but one could not expect a great change to be made at once. They were new materials, and their production and use had been going up by leaps and bounds for some time past. The big problem in the way of their utilisation was that it was very easy for a designer to use his slide-rule on these materials and say that they did not offer an advantage in compressive strength and that the modulus of elasticity was low. That was true, but the American designers used these materials after doing that calculation, taking the view that, while they could not be put in a main spar of a wing or at the top and bottom of the fuselage they could be used at the leading edge of a wing. That was satisfactory and was being done in this country. They could also be put in the sides of the fuselage, where it took shear, and they had a considerable weight advantage there.

The basic problem in this country in getting that accepted was that the aircraft industry had had to learn a great many tricks, as compared with the old engineering industry, in order to utilise light alloys and, having learnt those tricks, was busy putting them into production and had not much time to spare to learn the new tricks of the trade required to utilise magnesium alloys.

As a magnesium technician himself, his problem was how to form this material. He said that it was necessary to form it hot, and then people said: "We are only set up for cold forming." That was one of the biggest objections which he had come across. It was always a pleasure, having convinced someone that he would not lose much by hot forming, to see his smile when he found that secondary problems such as spring-back allowances and so on disappeared automatically under such conditions. The short answer to Mr. Brown was that magnesium alloys, and particularly magnesium-zirconium alloys, were being used to a consider able extent in this country.

Mr. A. Vines, (*Production Manager, Fairey Aviation Co. Ltd.*) said that it had been brought home to him, and he thought to most of those present, that there were many problems coming before the aircraft industry which required colossal capital investment. His company had done one or two jobs which were a little out of the ordinary on a small scale. When considering something on a bigger scale, for example the making of wings out of one piece and of enormous machine tools there was a tendency to forget that, having made a large component in one piece, it was necessary to heat-treat it and deal with the problem of distortion.

Those were problems which had to be faced by somebody. The subject had now been discussed for upwards of two years. They had been told that the Americans had made wing skins out of large slabs at a cost of anything from 20 to 50 per cent. less than by the ordinary method, but as a nation—he was not talking about individual firms—all that had been done was to talk about it.

The members of the Conference represented the Ministry and the design and manufacturing sides of the industry. If as a nation they did not wake up and decide to do something about it, they would go on being told about what the Americans had done, by the use of titanium, for example. So far as he knew there was only one firm in this country which used it.

He had always been told, and believed it to be true, that research in this country was better than research in America. As a nation we spent colossal sums on non-productive projects but not enough on doing things which were worth while, because we were half afraid of ourselves; somebody said: "That will cost a lot of money, and therefore we cannot do it." If the aircraft industry was to earn all the money which it was hoped that it would earn by exports in the next twenty years, the whole nation had to think far more seriously about who was going to spend the money. To get a slab more than 2 inches thick to make the job had already taken eighteen months, and they had not got it yet; it might be another eighteen months before they received it. They were all interested in the problem, and if they did not put their heads together and get a more realistic outlook they would not only be behind the Americans today, but in ten years' time be so far behind them that it would be very difficult to catch up again.

No one so far had mentioned casting. Mr. Vines' firm had been doing what they called precision casting, which came out within 1/32 inch or less up to a weight of 14 lb. The best way to make a thing the right shape was when it was fluid and one could put the metal where one wanted it. If they could develop the type of casting technique used in the marine industry for many years, where very big, heavy steel castings were made, that might be a good alternative. In the meantime, until there were the facilities to make castings, there was the alternative of making big forgings, and there was the very good alternative of making them from slabs, but to do that it was necessary to have the material and that was not yet available. He appealed to the aircraft industry to get some money for long term manufacturing development

Mr. A. A. Jacobsen, (*Works Manager, Normalair Ltd.*) strongly supported the last speaker. As a production engineer, he said, his nightmare was the recommending of the purchase of plant which might stand for many years in a factory as a monument to his folly. They all knew that fear, and many pieces of plant were standing idle in factories today because they had hoped the designer was going to continue to call for some particular method of production.

They had heard something about designers having to know all about production, but very little about the need for production engineers to know a certain amount about design. He thought that one solution of the problem discussed earlier would come when production engineers began to get a firmer grip on some of the design problems. When Maudslay invented his "go cart" or carriage for the lathe he had a very clear understanding of the design

(*Concluded on page* 119)

"PRODUCTION PROBLEMS ARISING FROM THE TREND OF DESIGN (FROM THE VIEWPOINT OF AN EQUIPMENT MANUFACTURER)"

by G. H. DOWTY, F.R.Ae.S., F.I.Ae.S., M.I.Mech.E.

(Presented by Sir Roy Fedden, M.B.E., D.Sc., F.R.Ae.S., in Mr. Dowty's absence)

Mr. Dowty was born and educated in the West Country and has spent all his life in the aircraft industry, first with Heenan & Froude, then with British Aerial Transport, A. V. Roe, and the Gloster Aircraft Company.

He founded Dowty Equipment Ltd. in 1931 and is now Chairman and Managing Director of the Dowty Group, with six English and three overseas companies in Canada, Australia, and the U.S.A.

Mr. Dowty was President of the Royal Aeronautical Society, 1952-53.

Mr. G. H. Dowty

WHEN I was invited to read a Paper on Aircraft Design trends from the viewpoint of the Equipment Manufacturer, I was glad to accept for I believe that the complexity of present aircraft equipment is little understood.

I realise that it is impossible to cover more than a small section of this work and, as I am not qualified to deal with such vital groups as those covering electronics or many other important sections of the aircraft equipment industry, I shall review part of the field with which I am associated, that of mechanical equipment. I propose, in this short Paper, to consider two or three components as representing this work in general.

Two Main Categories

Aircraft equipment falls into two main categories:

1. Tailormade items to suit the requirements of a particular airframe or engine.
2. Standardised items.

In the first category fall such components as landing gears, actuators, etc.; in the second category, pumps, control valves and instruments.

Standard equipment is normally designed on a long-term basis with ample time for development and careful production layouts. This results in a flow of highly developed units, economically produced with a minimum number of modifications.

How different is tailormade equipment! The time taken to get final design settlement, the shorter period normally left for production and the smaller output, does not permit of the same thoroughness as that given to standard equipment. Whereas we do not expect many modifications on standard components, we accept these as part and parcel of the shorter-run tailormade article.

You will see then that aircraft equipment embraces two widely differing types of product and this Paper is, accordingly, divided into two parts.

In recent years, much higher performances have been required of aircraft equipment and coupled with this has been the insistent demand for weight reduction.

Thin wings have increased the difficulty of stowing the undercarriage when retracted, and the use of jet turbines has, in general, reduced ground clearances and made for shorter undercarriages. At the same time, higher landing speeds have resulted in the need for greater shock absorption. It is no wonder then that designs have become more complex, with the resulting products requiring more elaborate tooling and greater skill from the Production Engineer.

Higher performances from hydraulic pumps have been made possible by substantial increases in operating pressures and, in the case of fuel pumps, by up-speeding. The use of water-based fluids and of fuels with non-lubricating properties has called for intensive research to provide better bearing surfaces.

and present-day production techniques are leaning more and more on the chemist and the metallurgist.

PART I

TAILORMADE EQUIPMENT

Undercarriages

Present trends in aircraft design have emphasised the importance of weight control and dimensional accuracy, and the effect of these on landing gear production has involved :—

1. Machining fittings all over to maintain accurate weight control.
2. The use of higher tensile materials; 100 ton steels are now being used successfully.

Dealing with the first point, the following illustrations will show the problems which arise on prototype and production work :

Fig. 1 shows a typical prototype undercarriage fitting and the light alloy billet from which it is made. The billet weighs 608 lbs., the finished part 74 lbs.

Fig. 2 is the production counterpart of the fitting shown in Fig. 1. The die forging weighs 175 lbs. and the finished part 61 lbs.

Fig. 3 shows another typical prototype fitting made from steel. The billet weighs 538 lbs. and the finished part 78 lbs.

The die forging shown in Fig. 4 weighs 74 lbs. and the finished part 27 lbs.

Fig. 5 shows a magnesium zirconium casting for a large undercarriage. The weight of this casting before machining is 489 lbs. and finally machined 439 lbs.

Fig. 6 shows a smaller casting; the weight as cast is 306 lbs. and finally machined 281 lbs.

In general, it can be said that for prototype fittings made from hand forgings, it is necessary to machine away 90% of the billet. On production, the figure is better but still much too high at 60%.

Fig. 1

Fig. 2

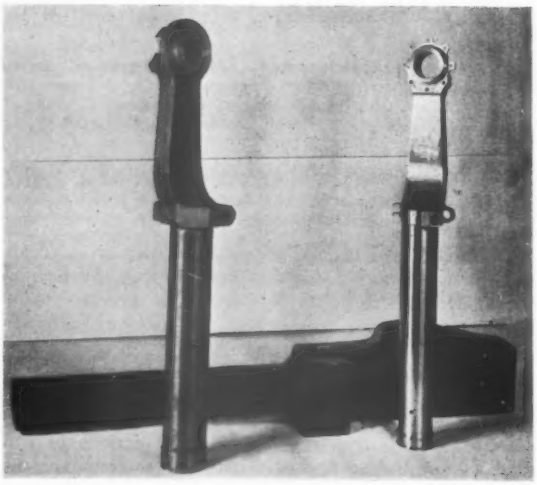


Fig. 3

Fig. 4

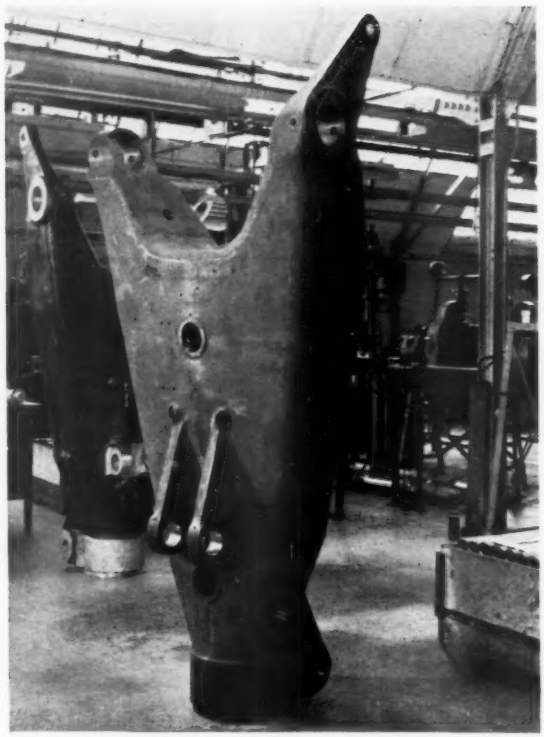


Fig. 5

From the production standpoint, castings are extremely attractive since very little machining work is required to produce the finished part. As an indication of this, only some 9% of the material is removed during machining, which is advantageous when compared with the percentage quoted above for forgings.

However, the low strength of a casting is a serious deterrent since except under favourable applications a weight penalty results and for that reason their usage is limited.

From an economic point of view, the casting has much in its favour and should encourage the material suppliers to provide alloys of greater strengths.

At the same time, much greater improvement in the accuracy of hand and die forgings is necessary. I am sure that industries in a keen and competitive market would never accept production forgings in which two-thirds of their weight required removal by machining.

Machining

The trend of design of main and nosewheel undercarriages in meeting the exacting demands of present-day aircraft, has been a challenge to the skill and ingenuity of the production and inspection departments. Briefly, the problems which have arisen are :—

A. The machining of complicated shapes to save weight (Fig. 7).
B. The use of high tensile steels to reduce size and weight.
C. Closer limits particularly in linkage groups and attachment points.
D. The need for improved surface finishes. Measurement in micro inches, a curiosity ten years ago, is now a standard requirement.

How well the challenge has been met is shown by the way in which 100-ton tensile steels are being used. Only a few years ago, these materials were regarded for all practical purposes as unmachinable, but today these difficulties have been overcome. Improved production techniques include :—

1. High speed fast feed milling of a DTD. 331 forging using a tungsten carbide blade cutter. (Fig. 8.)
2. Accurate rough machining before final heat treatment to reduce final machining.
3. Frequent inter-operation magnetic crack detection to avoid wastage of labour.
4. Modern boring methods to reduce the problems of deep hole drilling.
5. Rough and finish grinding and honing operations to ensure high surface finishes and extreme accuracy of size. Fig. 9 shows the grinding of bores with a tolerance of .001". Finishes of the order of 1 to 2 micro inches are obtained with the complete elimination of surface blemishes such as flick marks.

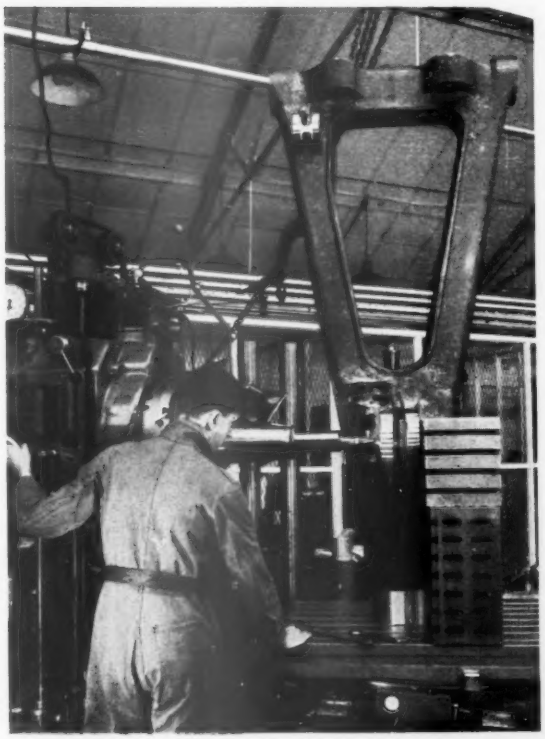


Fig. 6

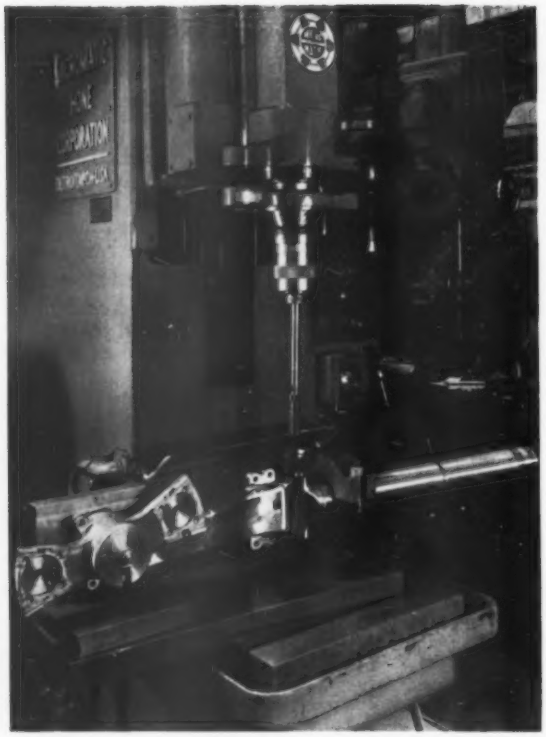


Fig. 7

6. Intricate machining is facilitated by the use of Hydrotel Copying Machines.
7. Fig. 10 shows milling cutter gangs producing related faces within limits of .0025". Multi-milling cutter set-ups ensure a high degree of accuracy of related dimensions.
8. Detail interchangeability involving hole centre tolerances in the order of .0002" is achieved by improved jigging and tooling. Fig. 11 shows a master receiver gauge—these gauges are provided for the inspection of all major components.

Fig. 8

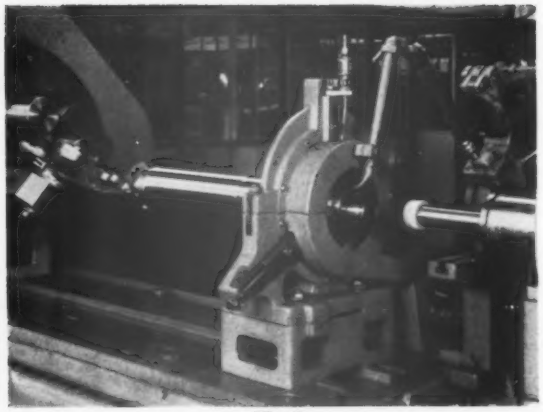


Fig. 9

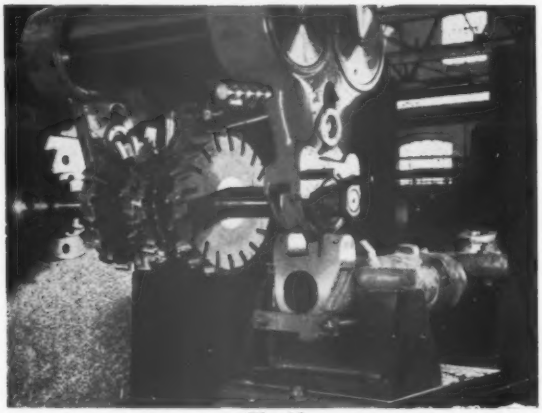


Fig. 10

As a result of present design trends, undercarriage equipment has become more expensive to manufacture and calls for greater skill in planning and inspection and greater capital outlay for machine tools and other equipment.

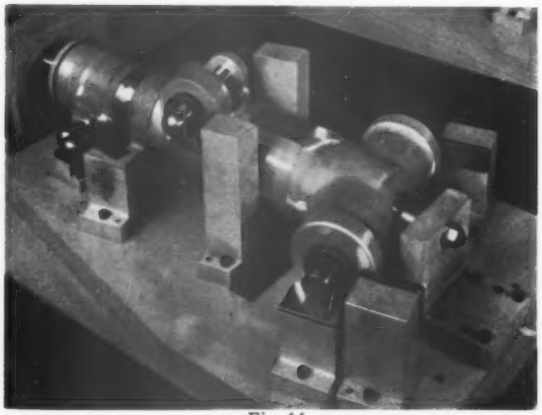


Fig. 11

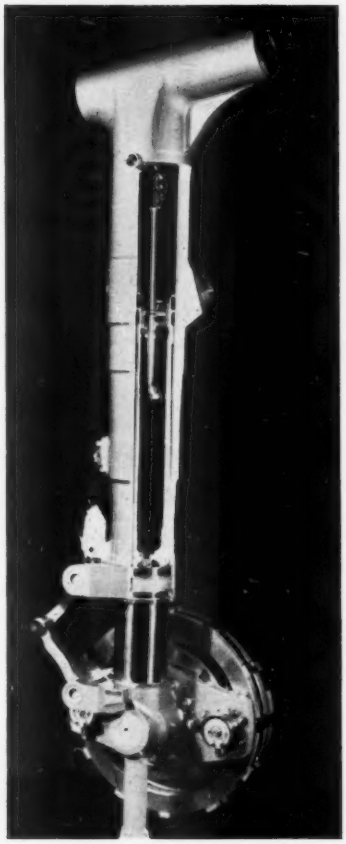


Fig. 12

Figs. 12 and 13 show examples of the complexity introduced to save weight. Fig. 12 illustrates a fighter undercarriage leg with the brake elements mounted on a flange bolted to the shock absorber axle fitting. Until recently, this was the accepted standard method. Fig. 13 shows a recent fighter undercarriage leg with the brake mounted on lugs machined integrally with the shock absorber strut. The increased machining time for this integral design is in the order of 18 hours per fitting and the weight saving 3 lbs.

Of course, there must be a limit to the minimum saving per manhour that is economically justifiable. Perhaps an aircraft designer would care to suggest an acceptable figure.

I have already mentioned that the thin wings of modern aircraft result in highly restricted stowage spaces and this necessitates very accurate assemblies. As an example, on a current fighter undercarriage, the angle between the retraction shaft and the axle is held to a tolerance of $\pm$ 5 mins. of arc. When it is realised that this tolerance is affected by four separate details, some indication will be obtained of the accuracy of manufacture required.

The importance of weight reduction has resulted in designers pressing forward with investigations for means of substituting light alloy for steel parts.

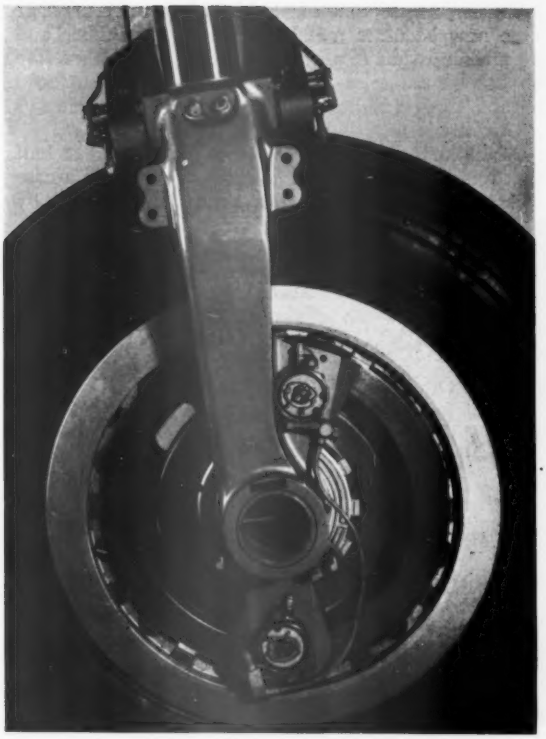


Fig. 13

The use of hard chrome surfacing on steel sliding parts has provided a first-class resistance to abrasion This has resulted in the use of steel where for actual strength requirements the part could have been manufactured in light alloy.

It has, for some time, been realised that the anodic film used for the protective treatment of light aluminium alloys is essentially very hard, consisting as it does of aluminium oxide which in other forms is one of the most widely used abrasives. It is appreciated that by the use of a sulphuric acid bath of special composition and the maintenance of low temperature during the anodising process, it is possible to build up a film of substantial thickness (.002″ in one hour's treatment). Until recently, no attempts appear to have been made to exploit this process.

Investigations on a commercial basis were started about the same time both by William Campbell and my Company in England and by Glenn Martin in the U.S.A. We are now making extensive use of the process.

It is of interest to note that thick anodising has better wear resistance than hard chrome plating. A very similar process is now being carried out on magnesium.

Fig. 14 illustrates a modern bogie undercarriage with some interesting production features. The shock absorber, springing and bogie ground trimming are all combined in one small self-contained pin-jointed

cylinder unit, so that the large sliding undercarriage tube now becomes merely a structural member and its surface is not required for sealing. It is therefore an ideal application for a light alloy tube surfaced with a thick anodic film. The outside diameter is 9″ and the length is 5′.

Machining time for this light alloy fitting is half that required for the steel counterpart. This is a case where saving in weight has been accompanied by greatly reduced machining time.

PART II

STANDARD EQUIPMENT

Fuel Pumps

These pumps are highly specialised pieces of aircraft equipment and are intricate mechanisms, running at high speeds and high pressure loading, and operating on petrol which has little or no lubricating properties. Satisfactory operation under such arduous conditions can only be assured by a high degree of dimensional accuracy and superb surface finish of the working parts.

Fig. 15 shows a pump which has been under continuous development for many years to satisfy the ever-increasing demand for high performances.

The rotor bearing and valve stem have required the most attention, due to their important influence on pump performance. This pump delivers petrol at 1,200 lbs. p.s.i., at a rate of 1,800 gallons per hour. The rotor turns on the valve stem at 4,000 r.p.m. It will be appreciated that the fluid leakage along the valve must be controlled within very small limits to maintain a high volumetric efficiency. The maximum permitted clearance between the rotor bearing and the valve stem can be no more than .0006″ and, to avoid risk of seizure, must not be less than .0002″. This, of course, means a maximum tolerance of .0002″ on the rotor bore and the valve. This is no easy problem, considering the bearing length and the 14 cylinder cavities in the rubbing surfaces. Fig. 16

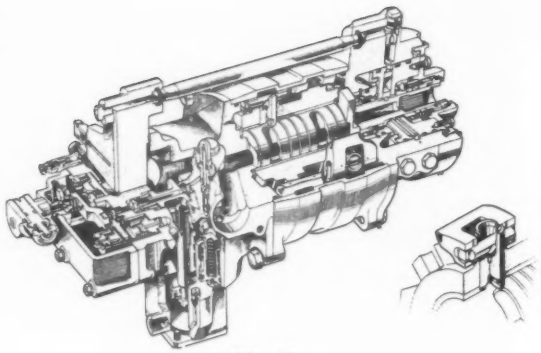


Fig. 15

Fig. 14

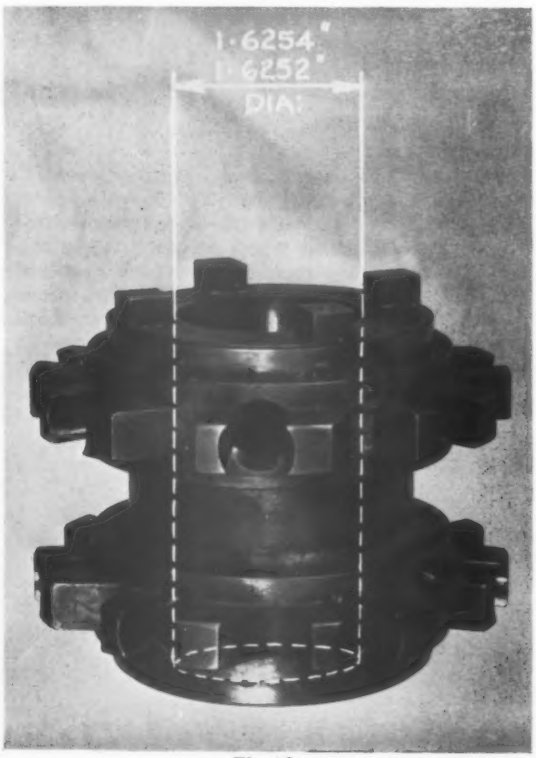


Fig. 16

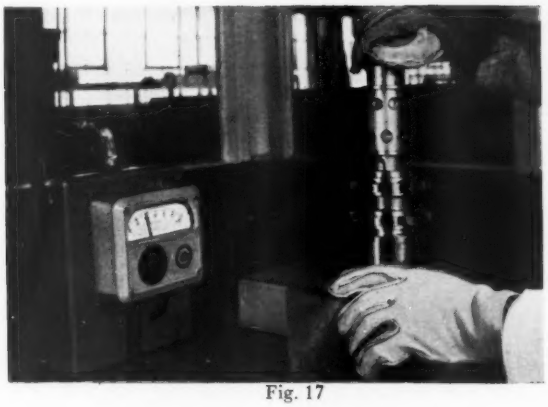


Fig. 17

shows the rotor detail with two banks of cylinders—7 in each bank.

Fig. 17 shows the rotor being fitted with a steel bush which has a centrifugally cast lead-bronze lining. It is located on a mandrel frozen to −40°C. and inserted in the rotor which is held at 150°C. After insertion, the bore of this bush is trued by diamond boring and is then tin plated.

Fig. 18 shows this plating being carried out by the use of a rotating anode to ensure the even deposit of tin around the bore.

It is difficult to plate to the fine limits required and a final broaching operation is carried out.

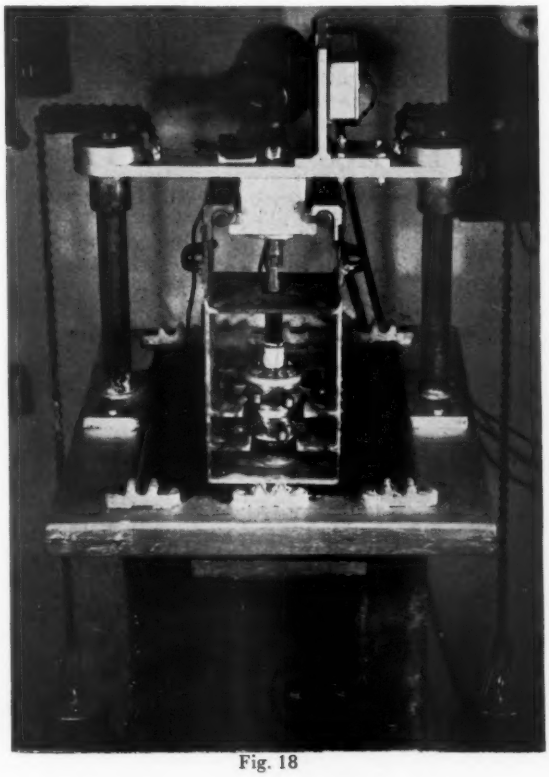


Fig. 18

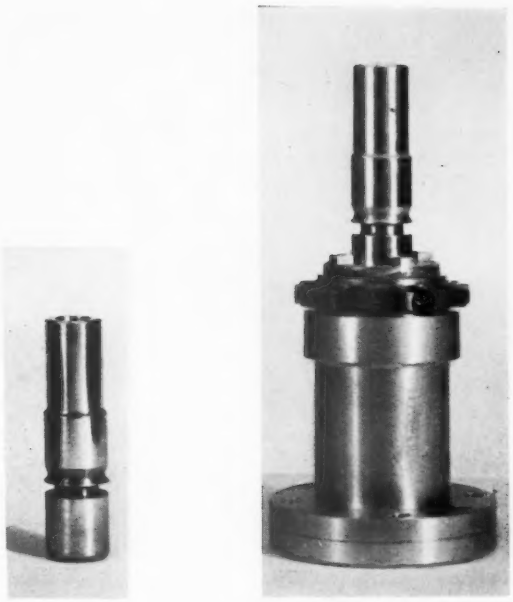


Fig. 19

Fig. 19 shows a location jig for the rotor and broach. Fig. 20 illustrates the special broaches used for this operation. The diameters of the broach on either side of the cutting edge act as guides for the broach as it

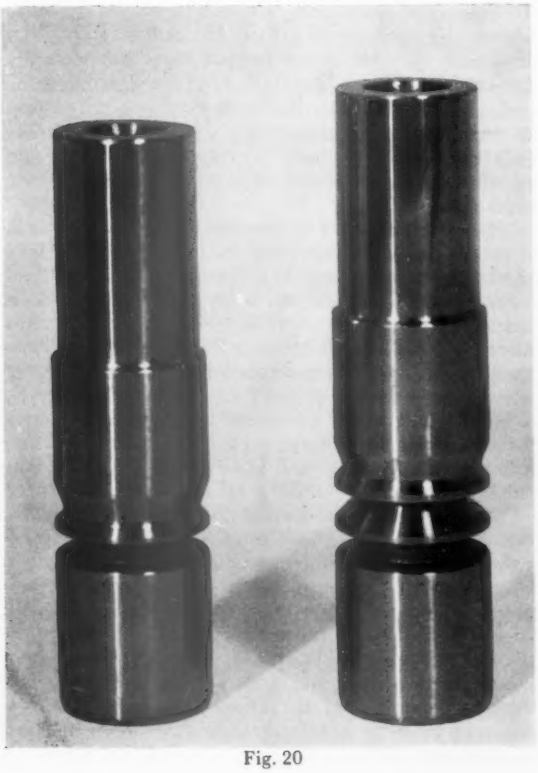


Fig. 20

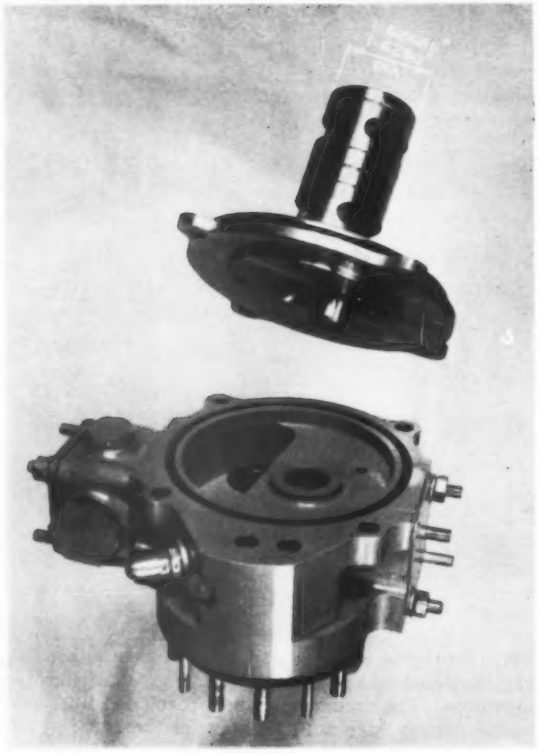


Fig. 21

is pushed through the bore. This manufacturing technique is an important contribution both to production and performance, for a dimensional accuracy well within .0002″ both for diameter, ovality and parallelism is maintained on a production basis with semi-skilled labour.

The valve member is shown on Fig. 21, the stem is made from nitralloy and the head, which forms the body for the governor, is manufactured from light alloy. As mentioned previously, the valve stem is made to a tolerance of .0002″, with a similar tolerance for parallelism and ovality. Reference has been made to the high surface speed of this valve member when running under heavy loads and unlubricated.

Rotors and valves produced by these new manufacturing techniques have proved satisfactory at high and low temperatures and have given good mechanical reliability and hydraulic efficiency.

There is no time to discuss the governor in detail, but mention will be made of the throttle by-pass valve (see Fig 22). The characteristics of the throttle by-pass valve are controlled by closely limited apertures. These are produced by three milling cuts, the edges of which are radiused to .005″ maximum to prevent cracking. The valve is then nitrided and lapped to finish size. This intricate unit is produced by careful control of the amount of material to be removed by final lapping and by the length of time of nitriding.

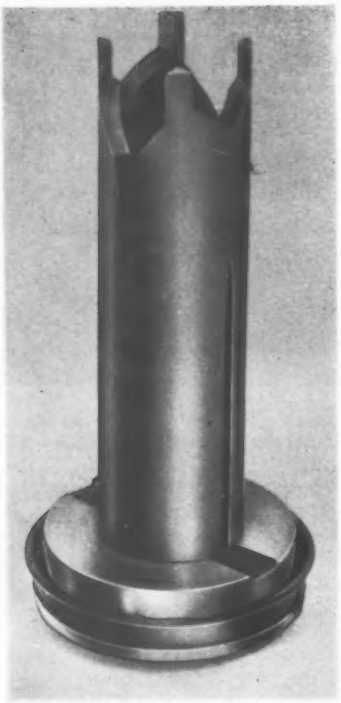


Fig. 22

Fig. 23 shows a plunger and slipper assembly. The plungers are made from nitralloy and are provided with a seat to accommodate an alignment ball made from a specially heat-treated cast iron. The diametric clearance between the plunger and cylinder bore is .0002″—.0005″ and the plungers are made to a tolerance of .0001″.

The provision of satisfactory working surfaces has called for an intensive research programme and good results are now being obtained with molybdenum di-sulphide impregnated surfaces; further developments are aimed at impregnating the surfaces with sulphur.

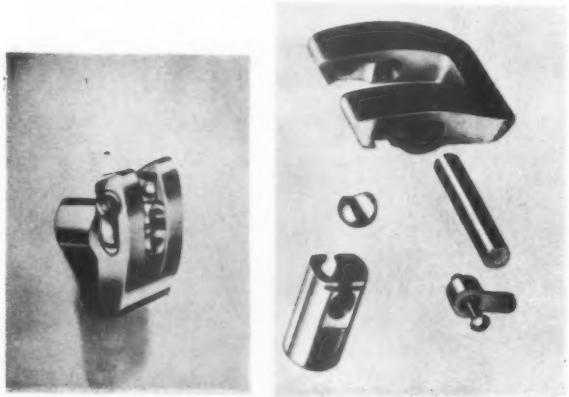


Fig. 23

The slippers are made from cast phosphor bronze and their contour is closely controlled for diameter and squareness to a fully floating gudgeon pin. The slipper surface is plated to provide an absorption medium for fine particles of foreign matter. The plating consists of a sandwich of tin/lead/tin, electrically deposited.

The gudgeon pin is retained by end plates produced from investment castings and retained in place by rivets, the heads of which are squeezed over to avoid slipper distortion.

Burners

Another fuel system component that has required a different production approach is the spill burner nozzle. There are usually ten or twenty nozzles per engine. The burner must ensure, at all altitudes and flows, the ejection of a fine atomised spray into each combustion chamber and it is important that flow output from each nozzle should not vary by more than ± 1½% throughout the operating flow range—which may be as much as 50 to 1.

Fig. 24 shows the burner details. These must be capable of resisting erosion and are, therefore, produced from hardened and tempered steels. The dimensions of all these details are closely limited, as each burner must have identical characteristics as to flow, spray angle and flow-pattern. These burners are manufactured to full interchangeability standards and call for the highest class of production engineering, as the many critical dimensions must be held to within .0002".

Hydraulic Pumps

Increases in operating pressures to 4,000 lbs. p.s.i. and higher, coupled with the requirements for operation with non-inflammable or water-based fluids, at high operating temperatures, have necessitated considerable development during the last few years. Once again, dimensional accuracy, accuracy of form and a high standard of finish are required on all working surfaces.

Current high pressure hydraulic pumps are designed to eliminate, as far as possible, bearing loads on sealing surfaces and bearing surfaces are freed from sealing duties. This enables the various mating surfaces to be designed to meet one requirement, although in most designs, the plungers still carry a small side load due to the actuating geometry.

The cylinder-piston assembly must have a minimum working clearance to minimise leakage of high pressure fluid. Cylinders are honed to give a tolerance on diameter of .0001". Plungers are centreless ground which may result in a multi-lobe shape and the finishing operation is individual lapping to restore circularity, the tolerance on diameter is .0001".

Fig. 24

Conclusion

What has been said will serve to show the exceedingly high class of workmanship called for on present mechanical equipment for aircraft. A few years ago the limits now required could not have been attained. As specifications have called for higher efficiencies, these have been met by research, development and the installation of high precision machine tools, measuring and testing plant.

Manufacture of these products has called for great skill and more and better production engineers. To meet this need my Company, some years ago, decided to influence more apprentices to take up production engineering as a profession and special courses were started at our local technical college. Whereas seven or eight years ago only a small percentage of our apprentices were interested in this work, about 30% are now passing out with production engineering as their main subject.

New methods, inventions and discoveries are forever a constant part in our search not only for better products, but for means of manufacturing with less effort. Behind all advances are initiative, enterprise and a creative activity that causes discontent with present performances but is accompanied by a vision of better things.

In all this we must have regard to the human side; allowance must be made for genuine efforts, though they fail and praise given for success, however little. In this way, the story of successful production is not merely of something mechanical, but one of enthusiastic and happy team work.

" PROBLEMS OF AIRCRAFT PRODUCTION " (*concluded from page* 78)

essential that that service shall continue; it is far more important for the inhabitants of those countries that that type of service shall continue than that the V.I.P. should be able to fly in a Comet at such immense speed.

The whole prospect is most challenging and intriguing, along the paths both of speed and of price; and the vague thoughts which must be passing through the minds of the designers today, and which will one day become aircraft, must be following those two divergent paths. On the fertility of mind of the designers and on the ingenuity of you production engineers depends in fact the future of this business, on which we rely so greatly to enable us to take our rightful place in the modern world. You have great advantages and great opportunities. My only doubt is whether there are quite enough of you.

"PRODUCTION PROBLEMS ARISING FROM THE TREND OF DESIGN"

by S. P. WOODLEY, M.B.E.

Mr. S. P. Woodley

Mr. Woodley has been Superintendent at Vickers-Armstrongs Limited, Supermarine Works since 1950.

He commenced his apprenticeship with Supermarine Works in 1927 *and has served the Company in various capacities.*

During 1942-43 *he was a Member of the Fedden Mission, which was formed under the auspices of the Ministry of Aircraft Production to investigate technical problems and new Developments in the United States of America.*

I WISH to speak to you tonight about the production problems which are emerging from the present trends of airframe design.

It is the task of the production Engineer to bring into reality the ideas of the designer. Each forward step is usually taken in the light of past experience. However, at some point a sharp divergence in ideas and practice is reached. Sometimes this is brought about by a new discovery, for example, the jet engine; sometimes by a natural barrier, e.g. Mach 1, and sometimes by a radical change in design practice, as was the case when metal replaced wood and linen as an aircraft production material.

I believe that we have now reached such a point of transition. The greatest change that lies ahead in the manufacture of airframe is concerned with the ever-increasing accent on machining, and a reduction in pure sheet-metal forming and assembly.

Supersonic speeds have made very thin wing sections necessary, and, combined with this, are the higher stresses which the aircraft must bear at such speeds. The thin wing has made the wing spar, as such, of different form; in fact, it may disappear entirely. Instead, the load is spread over a thick skin, which is sometimes integrally stiffened. I am speaking, of course, about high speed fighter aircraft.

Integral stiffening means that instead of riveting such things as rib booms, panel stiffeners, doublers, stringers and intercostals on to the skins, these are formed in one piece, either by machining or forging. The resulting component is, of course, stronger and lighter than its fabricated counterpart.

Concurrently with this, we find that the internal structures are increased in strength to such a degree that ribs, diaphragms, etc., can no longer be fabricated from plate, but are machined from the solid or from forgings.

A similar trend is taking place in fuselage construction. Where the last generation of aircraft were designed with frames fabricated from light alloy sheet, these are now appearing as forgings, which need to be machined all over. Integrally stiffened fuselage skins are also appearing.

The designer is now insisting that where stresses are light, skins and components must be integrally relieved, and where the stresses are high, sufficient material must be left to bear the loads.

The logical development of this would be the design of wings formed in two halves from slabs or forgings of light alloy, machined internally to form ribs, spars, fittings and skin in one piece. These are afterwards bolted together and contour machined all over externally.

This type of structure may pay dividends in the form of economy of time taken in production. Although the machining time may be very high, assembly times will be correspondingly low.

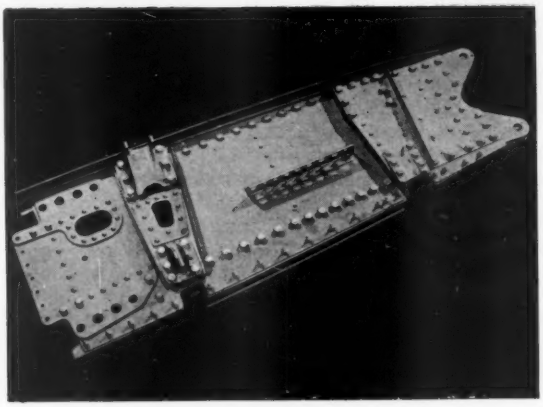


Fig. 1. A fabricated wing rib

The swept wing of today may be replaced by the razor thin wing of tomorrow. The swept wing has introduced problems associated with the assembly of ribs at an angle to the spars, so that these may be normal to the line of flight.

Implications arising from Design Trends

The current trends in design, as I have outlined them, indicate that there is a distinct revolution imminent in airframe fabrication methods. Until quite recently, the minimum of machine work was necessary for the production of components, which were largely fabricated from sheet metal by a variety of methods, such as press forming, hand forming, wheeling, stretching, welding, etc.

Such machining as was required was of a simple character; turning, for the supply of bolts, for the provision of fork ends, jacks, control rods, and so on. Milling was necessary for the production of spars, joint fittings, attachment brackets and mountings, etc., but the future lies in machining, with the accent on the milling function and, indeed, on a type of milling not encountered elsewhere.

This point is illustrated by Fig. 1 which shows a plate rib. This is composed of several distinct parts; the rib plate, stiffeners, attachment flanges and so on, riveted or otherwise assembled together.

Fig. 2 illustrates a machined rib, which consists of one piece only. It is machined from a forging. Unfortunately, it has to be machined all over, as we cannot yet obtain forgings with sufficiently close tolerances to meet our rigid weight control limits.

A fuselage frame (Fig. 3), similarly machined from a forging, shows an even wider disparity in the number of parts, as compared with a fabricated frame.

This means that the trend we have all experienced, namely the ever-increasing number of parts required to make an aeroplane, will be halted, and, indeed, it is safe to predict that it will be reversed. This is one of the things we find to the credit of integral machining.

The examples I have just mentioned are representative of the transition period through which we are now passing. We have not yet fully mastered the techniques necessary to produce complex shapes by machining, and we lack specialised machine tools. This limits the rate at which we can exploit the full value of integral machining.

When we have overcome all the difficulties associated with profile and contour milling on a large scale, it will be possible to reduce further the number of parts necessary to produce an airframe.

For example, where we now assemble machined ribs into a structure, and afterwards skin it with an integrally stiffened skin, development will almost certainly enable us to produce structures from a solid section by machining from a forged billet.

This will bring a welcome reduction in complication; it will reduce assembly times; it will result in a stronger structure, weight for weight. But it is dependent upon a determined attack upon the forging and machining problems which are involved.

We are all concerned at the increasing expenditure in man-hours which are necessary to produce new types of aeroplanes. I believe that we are now approaching the top of the curve in so far as comparatively small aeroplanes are concerned. I refer to fighters. The reduction in the number of parts, and the consequent simplification achieved will, when fully exploited, reduce the total number of man-hours involved.

Another result will be a reduction in tooling costs, for with a smaller number of parts there will be less tooling. If the development of milling machines proceeds on the right lines, we shall be able to machine complicated parts from simple templates, or line drawings upon metal; even from numerical information fed into the machine. We shall thus be able to speed up the production cycle.

All this will be at the expense of a much greater capital cost than has hitherto been thought necessary.

Production Development

The Production Engineer must keep abreast of design, and he should always be able to make the

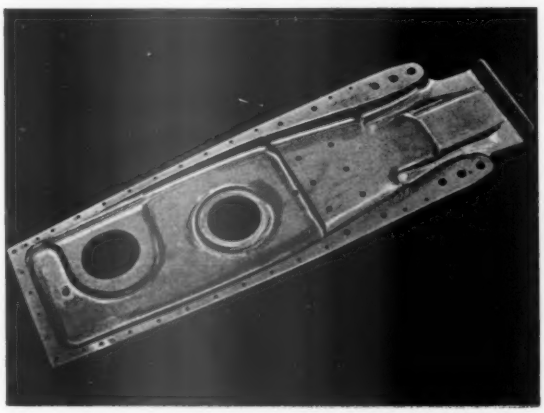


Fig. 2. A machined wing rib

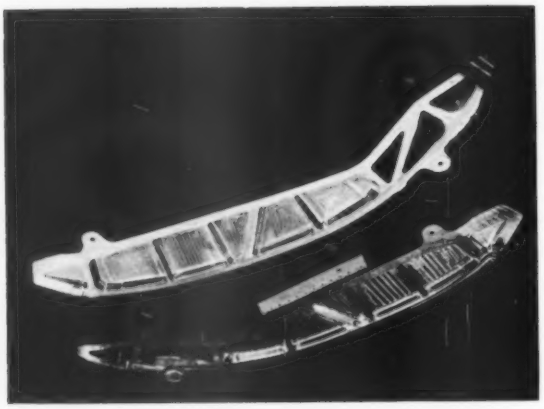


Fig. 3. A fuselage frame section, milled from the solid

machines or parts which the designer requires, as cheaply and quickly as possible.

Methods must always keep pace with design, and it must not be possible for the designer to design something which cannot be produced at that moment. Progress is a continuous process. The development engineer can help to make this process a logical one.

A production department, devoted to the development of new production methods and capable of coping with any new design technique, is a necessity. This department must be controlled by someone of wide experience, who can correlate the ideas of the department's specialist personnel.

Large sums of money are spent annually upon technical development in the field of design research; we must do the same in the field of production engineering.

This specialist department must have no routine duties or worries; its personnel must be free to undertake and solve problems as they arise, and they must be free of immediate production worries. Their function is to think much further ahead.

Close co-operation between the drawing office and the works is usually achieved in the form of liaison between production and design department representatives. The production personnel assist the design office by making suggestions to simplify the productive task. This reduces drawing amendments which might otherwise be necessary to cover production easements.

The need for production development goes deeper than this. Design project engineers are designing for the future. It is with them that the production development department must make contact.

Production research entails the search for production methods to match the design requirements of five or even ten years time; otherwise the works may lack the necessary technique. The engineers responsible, are in contact with the design project office at all stages, and may advise on what is possible at any one time and what may be possible in the future.

The development department will also act as a methods section, always in search of more efficient ways of doing a job. In aircraft production the field for improved methods is a wide one. Our industry is young and vigorous. It has always been ready to adopt and adapt. It has borrowed many techniques from other industries in the past; for example, the use of the router and spindling machine from the wood-working trades.

It has developed the rubber die press and the stretcher press, and later the Marform method of deep forming sections. It has adapted and improved the very old technique of tumbling to the problem of removing machining marks on components. I shall refer to this technique at a later stage.

Cheaper Machining Methods

The challenge which we now have to face is that of cheaper machining methods. It should be possible to adapt the ease, cheapness and versatility of the router technique to the problems of skin milling. The chief trouble in this case is one of obtaining an increase in accuracy, for skin thickness limits, at least as small as those which obtain on rolled plate, have to be maintained. I will show some slides later which illustrate possibilities in the use of the router technique for skin milling.

The Production Engineer must look far enough ahead to ensure that the tools necessary for any particular job are available in the factory in time to meet production requirements. In the case of the new techniques, capital outlay can be very large.

This places the engineer in a difficult position, in that it is possible that the design requirements which we are discussing may last for a very short time only, and then be superseded by some turn of events entirely beyond his control.

What I have especially in mind is this: America is producing large skin milling machines for the purpose of manufacturing integrally machined sections. Some of these machines cost around £100,000 to £150,000.

In order to meet an aircraft production programme, two or even more of these machines might be necessary. Such a capital outlay for short-term production, which might end as soon as the increase in aircraft speeds makes it necessary to change to steel or titanium, poses a problem.

This is one of the difficulties facing the production engineer who has to recommend large capital expenditure on plant, knowing that design trend is not completely stabilised. However, the machining of integrally stiffened skins and large forgings is with us for the next breed of aircraft, and methods must be found which will enable us to produce them. I believe that some simple solution will be found.

Problems Involved—Machines

The decrease in the thickness of wing sections, combined with the severe stresses imposed on aircraft in supersonic flight, has made the heavy structural member indispensable. A member which is made in one piece is stronger and lighter than one fashioned from an assembly of many pieces, whilst, because of its better grain flow, a forged member is stronger than one machined from a solid billet.

The trend is towards the use of large one-piece members, machined to close tolerances to conserve weight. We are, at the present time, tending to spend too long in cutting these members from solid billets of material. Much of this time could be saved if a really large forging press were available to the industry. It is possible for us to produce a limited quantity of aircraft from components machined from solid slabs of light alloy, weighing a ton or more, but large scale production cannot be sustained in this way.

If the large forging press were available, design technique would immediately avail itself of it, because of the benefits to be gained from the higher strength which results from correct grain flows, and the reduction of heat treatment problems. Designers are unwilling to create designs calling for large forgings unless the capacity exists to make them. Conversely, industry waits for the need to be created before provisioning the tools to satisfy that need. This vicious circle must somehow be broken.

Large Forging Presses

The American aircraft industry has laid down an extensive programme for the manufacture of large forging presses. The large forging press was first used as a production tool by the German aircraft industry during the last War. A press of 15,000 tons capacity was in use before the War, and eventually they constructed one of 33,000 tons capacity.

At the end of the War the Americans were able to secure the German press of 15,000 tons, whilst the 33,000 ton press was seized by the Russians. The American programme caters for further presses of 35,000 tons and 50,000 tons capacity. In this country, we have no forging press as large as those in America, and, so far as I know, bigger ones are not projected. This seriously limits the size of forgings which can be produced, and makes it necessary for us to machine our large components from extremely large billets of light alloy. This wastes both material and machine capacity, and if the present trend in design continues, it is imperative that we have presses installed in this country of not less than 35,000 tons capacity, and, better still, of 50,000 tons.

In order to obtain the maximum advantage from the use of large forging presses, a forging technique should be developed, capable of producing "Close to Limit" forgings, having the minimum amount of material to machine off to produce the finished component. This technique will necessitate the use of a succession of progressive dies to produce the forging; each die bringing the material nearer to the required form.

It may be that the production capacity of the forging presses will not enable us to exploit this technique to the full, but an endeavour should be made to do this on the most complicated parts. Because of the necessity to use a close weight control on all aircraft parts, it has been found necessary to machine most components all over, as the limits on forgings give a wide variation on the finished weight of the component if this is not done.

Fig. 4. A section of an integrally stiffened control surface

This is a forging manufacturer's problem, and it is aggravated by the fact that quantities of an individual forging are comparatively small. This means that the forging manufacturer must have a large tool room, with costly die sinking equipment. As he usually sells his products by weight, it will be difficult to sell him the idea of "Close to Limit" forgings on a small forging programme.

However, from a national point of view it would be far better if the copy mills, which are now employed in the aircraft industry for component machining and, in so doing, making tons of light alloy swarf, were to be employed in making the dies for the forging presses.

Having once made the dies, all the necessary heavy machining on the components would be largely eliminated, and the result would be a great saving in man-hours.

The forging press and its ancillary equipment is extremely costly. The American forging press of 35,000 tons capacity weighs approximately nine thousand tons, and measures 108 feet overall. I am informed that the cost of such a press is about £250 per ton, which means that total cost would be around two and a quarter million pounds.

This would not represent the total expenditure involved, as the press has to be housed, served by furnaces, heat treatment plant and other ancillaries. The saving in machine hours which result from production of "Close to Limit" forgings is vitally necessary to render the expenditure of such vast sums economic.

Copy Machining

Copy machining has, of recent years, become the best tool in the hands of the Production Engineer, both for milling and turning. Such machines are being increasingly developed, and the end may well be the completely automatic factory. Copy machines are today largely hydraulic, but a few are controlled electronically. Electronics may, in the future, allow

a machine operation to be controlled by magnetic tape, punched cards, or even by a computor which is continually working out the position of the cutter from drawing ordinates. There is a wide field for research here.

In the machining of such components as fuselage frames, wing ribs, etc., from large forgings, or even from billets, there are problems involved which, at the moment, cannot be met by existing copy mill techniques. Not only is it necessary to control the cutter around 360° in the flat plane, combined with control in the vertical direction, but it is also necessary to control the cutter on its axis, in order to provide for the machining of external and internal bevels.

This means machine control in three dimensions, combined with axial control of the cutter head in the two vertical planes. I believe that no such machine has yet been built. An American tool firm is building such a machine, which they call the Variable Axis (Variax) with copy control in each of these five movements.

At the present moment it is intended that this machine shall be controlled by steel templates and electronic tracers. Its capacity will enable it to machine a component up to 12 feet long and 3 feet wide. It is the manufacturer's intention to develop this machine so as to make the use of templates unnecessary. Numerical information will be fed into a computing device, which will produce a punched tape. This is later transferred to a magnetic tape, which will be used to control the movements of the machine to produce the finished form on the component.

This machine will reduce the number of tools required to produce a machined part to the minimum. It will be extremely flexible as new instructions to the machine, in the form of magnetic tape, can be quickly and easily produced. The machine will have an electronic memory, and instructions, which may be fed into the machine by hand, template or from numerical information, will be recorded on a tape which can afterwards be "played back" to reproduce exactly the required movements of the machine. For the machining of bevelled and angled machine parts, I believe that this type of machine will be the most simple which can be used.

Skin Milling

With regard to the specialised machine tool which will be necessary to provide for the purpose of skin milling, the case is somewhat different. The problem is two-fold; first technical, i.e. ways and means, and then quantitative; the provision of a sufficient number of machine hours to produce the programme.

At the moment the integral milling trend in America seems to be towards the production of skins having stiffeners which are parallel to one another. On the other hand, the trend in this country calls for a wide variation of reliefs, stiffeners and rebates. Most designers have a different approach to the

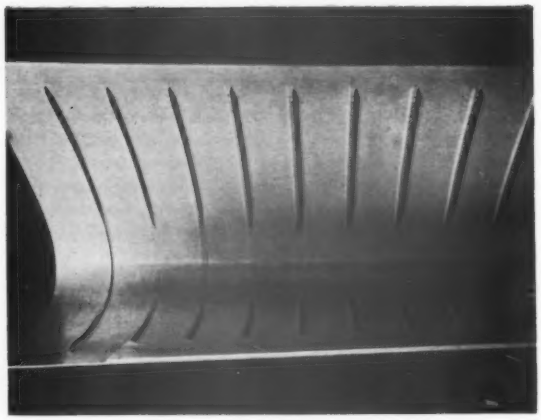


Fig. 5. A section of an integrally stiffened leading edge skin

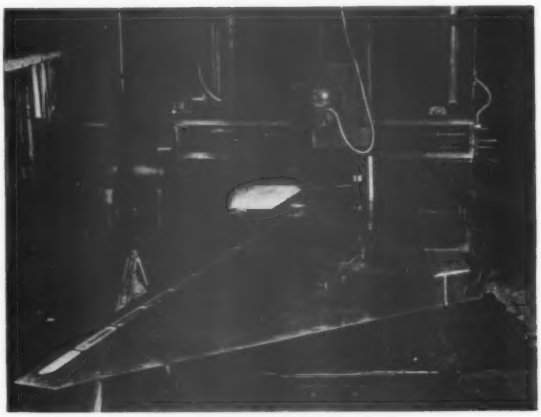


Fig. 6. A relief milled wing skin panel

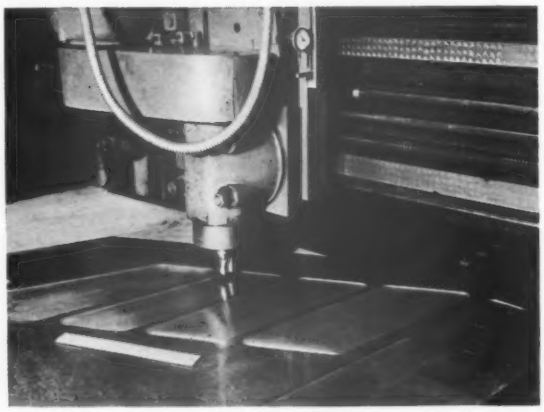


Fig. 7. Close-up of the reliefs in the skin (Fig. 6)

integral technique, and what is required is a machine, fitted with both vertical and horizontal milling heads, capable of copy milling in three dimensions. At the present, the choice of large machines to do this function is extremely limited. I know of no one machine that will machine skins with converging integral stiffeners, combined with a tapering basic skin, pockets forming thickness reliefs on the least highly stressed parts of the skin, and all manner of rebates.

Some of the types of stiffening and relief milling which are being encountered at the present time, are shown in Figs. 4 to 7 inclusive.

Fig. 4 shows an integrally milled and stiffened control surface.

Fig. 5 is a photograph of a section of an integrally stiffened leading edge skin.

Figs. 6 and 7 show a relief milled wing panel and a close-up view of the relief. The skin is 18 feet by 6 feet.

I promised earlier to make some suggestions as to how it might be possible to adapt the router technique for the machining of such skins. Fig. 8 shows two radial arm routing machines, mounted opposite each other across a roller conveyor platform. Each router will reach only across one half of a six-foot sheet, but by disposing them as shown, the whole width can be covered.

Since the radial arm will sweep across a 3-foot arc only, the sheet is machined in a series of swathes, and is moved along the table as each area is completed. To obtain accuracy from the machine, vacuum tables are mounted under the area to be cut, and the radial arm is supported on a bridge and carriage system. Thus it will machine on a perfectly flat plane.

The operators sit on bridges extending over the machine and guide the cutter heads under the control of a template, which is bolted rigidly to the skin that is being machined. The operators may move themselves across the machine at will, as their carriages are driven by small geared motors.

Fig. 9 shows a similar but smaller machine which may be used to machine pockets and reliefs, etc., on solid billets of light alloy. The machine carries a 5 h.p. router head, mounted in a vertical slide. Upon a longitudinally moving bridge, which extends across the machine, is mounted a carriage which moves in the transverse direction and which carries the cutting head. The cutter will, therefore, move across the whole area of the table within the limits imposed by the length of the slideways. A vacuum chuck is mounted on a table under the work-head, upon which the work can be clamped by vacuum or be jigged or bolted. The template which controls the cutter head movements, is mounted upon a platform above the machine. Two hydraulic jacks, connected to the cutter carriage, and a tracer and servo system, operating in the template, provide for effortless control of the machine by the operator through the medium of a "dead man's handle". These machines will be comparatively inexpensive in relation to the cost of a skin milling machine. If they prove successful, it will be possible for us to have a whole bank of them operating at a fraction of the cost of the large machine tool.

A good deal of experience has been gained in the holding of sheet metal while it is being machined. The most usual method is to hold it on to a surface by air pressure by the use of a vacuum chuck (Fig. 10). A vacuum chuck is a machined surface, bearing a seal around its outer edge, and provided with means whereby the air can be withdrawn from underneath any sheet of metal placed on the top surface. Excellent vacuum pumps are now available, and they are both reliable and cheap. A reservoir should always be interposed between the vacuum and the chuck, as, in order to pull the sheet into contact with a chuck surface, it is necessary to provide a sudden

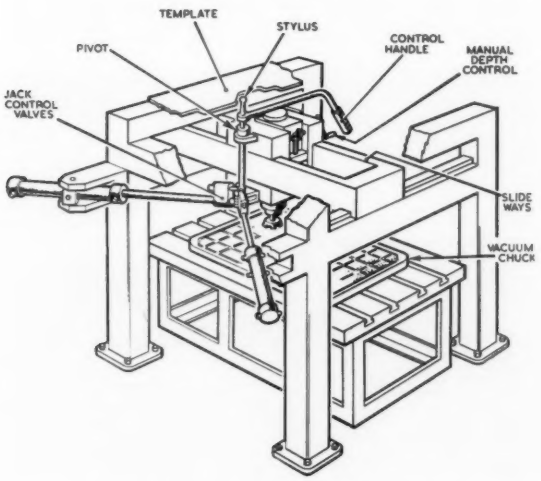


Fig. 8. Sketch of a router skin milling machine

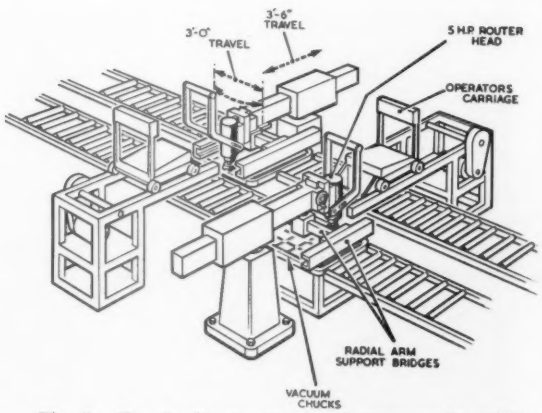


Fig. 9. Sketch of a servo-operated router pocket milling machine

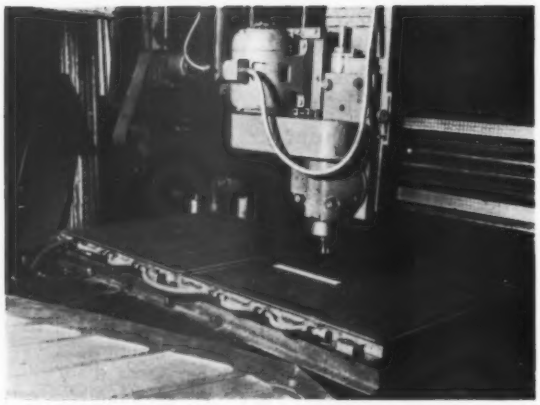


Fig. 10. Vacuum chucks

surge or variation of pressures. This is obtained by exhausting the reservoir by the vacuum pump and suddenly opening the valve connecting the reservoir to the vacuum chuck. Sheets which are slightly distorted can be pulled into perfect contact with the vacuum chucks by the use of this technique.

With the continuation of the integral technique, development will take place along the lines of the American skin milling machines, which will result in a reduction of their cost and increase their range and versatility.

If the integral technique is carried to its logical conclusion, whereby a wing is formed in two halves from large forgings or solid billets, then another type of machine will be needed. This will be required to machine the external contours of wing surfaces. In this case the cutter must be presented tangentially to the surface of the material in order to generate the aerofoil curve.

I envisage such a machine as having two tables, one at either side of the machine, at the centre of which is a moving carriage containing the cutter head and the tracing mechanism. On the rear table will be mounted the master form, over which the tracer will operate and control the cutter which machines the component mounted on the worktable at the front of the machine. There are a number of variations of this machine being developed at the present time by several firms.

Future Developments

The continuing development of the technique of machine control from numerical information will almost certainly extend to such a machine for the machining of external contours. The cutter head will follow a path determined by a computor, which works out its position from X and Y ordinates. I also believe that further simplification of skin milling machines will take place as development progresses, in so far as it will be possible to machine rebates, reliefs, integral stiffening and so on direct from a drawing, by using an electronic eye.

Fig. 11 shows a wooden mock-up of a machined fitting. It is always a good idea to make such mock-ups of complicated fittings, as this gives the design office a chance to see them in the flesh. It is also helpful to the planning and jig and tool offices, in devising the operations and the tools and fixtures. It enables the shops to envisage the finished shape and to try out certain cutters to see if they will reach into awkward places, and so on.

With the inevitable introduction of steel into the manufacture of airframes, problems will arise in the machining of high tensile steels. In order to achieve the best strength/weight ratio, these steels will be in the neighbourhood of 100 tons tensile.

Here the problem lies in the provision of cutters; in increasing cutter life, and in decreasing the cutting time. Because of the extreme toughness of the steel the finish obtained is generally poor. However, such steels are notch-sensitive, and a fine finish must be obtained to remove stress raisers. A finishing or polishing operation is nearly always required, and the rougher the basic machine surface, the longer will be the time taken to finish the components. There is, therefore, immediate need for an investigation into the machining of high tensile steels. The use of carbon dioxide as a cutter coolant may increase the cutter life and improve the finish. The Americans have used high pressure oil jets at the cutting edge to the same end.

Metal of the Future

The metal of the future may well prove to be titanium, and there is the whole field of research open in the fabrication and machining of this metal, as so little is really known about it yet. The metallurgists will be busy for a long time, developing alloys of this material. Each new alloy will bring with it fresh applications of design, and new fabrication problems. At present, only commercial pure titanium is available in this country, in sheet and bar form. Some forging manufacturers are also experimenting with it.

Present experience indicates that pure titanium is as readily machinable as high tensile steel. It can be welded quite easily by the argon-arc process, but it is difficult to bend and form. I believe that when

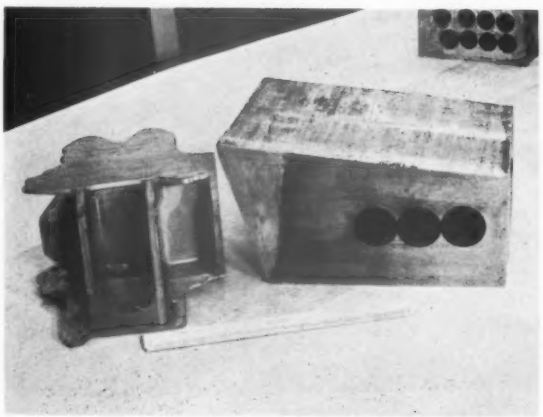


Fig. 11. Wooden mock-up of a machined fitting

high strength alloys of this material are available, this position will be changed, and we shall find it extremely difficult to machine and fabricate them.

At present, there are limits to its use in airframe manufacture. Because there is an insufficient quantity of it available, the introduction of titanium on a large scale for this purpose cannot take place immediately. This condition will apply for some years to come, unless some revolutionary method of producing it appears. There is also the lack of development of high-strength alloys which must come before it is fully acceptable as an engineering material for structural and stressed members. Moreover, it is extremely expensive, although its cost will fall when it is produced on a large scale.

This does not mean that the metal can be ignored for the time being. It is necessary to institute immediate research into its fabrication, both experimentally and in production, in order to gain experience in its use. Unless we do this we shall delay the inevitable introduction of this material into the manufacture of airframes, and will thereby lose some of the benefits to be derived from its better strength/weight ratio as compared with steel and light alloys. At the moment the advantage of this metal lies in its substitution for stainless steels for firewalls, heat reflective surfaces, blast tubes, wing sheathing around gun ports, and so on.

If a start is made by using it productively for these purposes, we shall at once obtain the benefit of reduction in weight, and gain production experience in manufacturing techniques, which will serve us well when titanium comes into general use. We have yet to learn the best ways of machining, forming, welding, forging and treatment of this new material. We can only do this from practical experience, and it is evident that we must introduce titanium into our designs and production as soon as possible.

I have been talking mainly about military aircraft, with the emphasis on fighters, but all aircraft show a decrease in the thickness/chord ratio of wings. This brings with it an increase in the thickness of wing skins. The powered rolls at present in use in the aircraft industry are not suitable for thicknesses much greater than 6 SWG in light alloys. We may soon have to form skins from high tensile steels. There is, therefore, a need for the development of powered rolls of much higher power than are at present available, to enable us to form these thicker and stronger skins. Where there is integral stiffening of the skins, the problem of forming becomes worse. One method is to fill up the spaces between the stiffeners with flexible packing pieces, such as fibre, and then roll the skin.

It is difficult to stretch-form the skins, in view of the non-uniform section; but it is not impossible, and some development must go on in this direction. It may be that the use of top and bottom tools to form a die through which the material is stretched may prove to be a solution. Some forming of skins using controlled shot peening has been carried out. This causes curvature through the work done on the surface of the skin. The preliminary work in this direction should be extended.

Heat Treatment Problems

As the design technique involving the use of components machined from large billets or forgings becomes more general, heat treatment problems will increase.

It is usual to carry out rough machining in the annealed state, because of the distortion which is experienced during machining, and also to achieve the highest strength in the finished component. The locked-in stresses in some of the billets which have to be machined are such that it is impossible to work upon them in the hardened condition. With every cut the material seems "alive", and moves to such an extent that subsequent cuts will not clean up.

This is a difficult problem as, on the one hand, distortion is experienced if the material is machined in the fully heat treated state, and on the other, if it is heat treated after rough machining considerable distortion is experienced during quenching. In respect of double heat treatment materials, heat treatment often results in dimensional changes in the shape of the component. The dimensional changes can be allowed for by leaving sufficient material on to enable the finishing cuts to clean up to size. At the present time distortion is such that a good deal of expensive straightening after heat treatment is necessary.

A technique must be evolved which will enable us to heat and quench with the minimum of distortion. This may be possible by heating in a vertical muffle and quenching by water spray, or it may be necessary to heat and quench the component whilst it is trapped in a die, in order to avoid the necessity for wholesale correction of distortion after solution treatment.

A particular case is illustrated by Fig. 12. This is a wing spar fretwork measuring eleven feet by five feet, machined from a solid slab of light alloy weighing 850 pounds. Its finished weight is 105 pounds. Each spar and rib section is of a different shape; tapers blending into flats, with differing thicknesses and so on. It is necessary to machine this in the annealed state and then to bend to the form of the wing.

Fig. 12. A fretwork machined wing spar

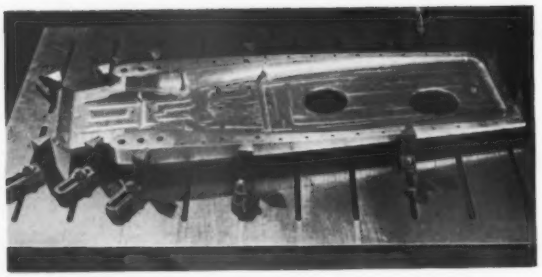


Fig. 13. A universal inspection fixture

The subsequent heat treatment, although carefully carried out, introduces such distortion as to make it necessary to spend many hours in correction. If it were possible to heat and then bend and quench this in a closed die, very many hours would be saved.

The future introduction of high tensile steels in the production of airframes, indicates that research is necessary into the machining problems involved. Electrolytic machining on a small scale by the Sparkatron process is already developed, and with this process even the hardest materials can be machined. Is it beyond the bounds of possibility that it could be developed to challenge and even supplant some of the machining methods in use today?

Summing up production methods, it seems to me that the future will see the accent on machined components where once we produced from sheet metal, combined with a decrease in the amount of sub-assembly and final assembly work which is at present required. The time taken to produce the details which go to make an aircraft may increase considerably because of the machining involved, but this should be more than balanced by a reduction in the total amount of tooling required and the time taken to assemble the finished components.

Machining, as a process, is very much more accurate than sheet metal working, and this will make the detail parts fit together more accurately, whilst the production of larger components in two halves, which are then bolted together, will shortly render unnecessary the complicated and expensive building fixtures which are essential to production at the present moment.

Inspection

With the increasing use of machined components in the design of aircraft, our inspection problems become greatly magnified. It has been the custom to inspect sheet metal component parts by accepting them from tools and out of jigs, etc., once the tool has been passed. This we cannot do to such an extent with machining. We need to remove as much of the skill as possible from the inspection function, in order to reduce the time it takes and to enable us to use unskilled labour. Such a policy involves the use of inspection fixtures, which may be produced solely for use on one part only, or be of universal application.

Fig. 13 shows an inspection fixture of a universal

Fig. 14. Component parts of inspection fixture

type which is set by a skilled man from a master component or a master template, and which is then used by unskilled labour to check the production batch.

The component parts of this fixture are shown in Fig. 14. Any such short cuts as I have illustrated may be taken to lighten the inspection load. Fig. 15 illustrates this point. It is an optical comparison machine, and is an extension of the epidiascope principle. In this machine the master component or template is mounted on one of the tables in the machine. On the adjacent table we place the component to be inspected. A source of light is thrown on to both components and the reflected light is passed through two lens systems into the machine. The images are projected on to a ground glass screen which is 30 inches square, so that they are superimposed. The image in one system is coloured blue, whilst the other is coloured red. Any difference in size between the two will show up as a colour fringe. Various magnifications of the objects can be achieved by changing the lens systems.

With large components and large magnifications,

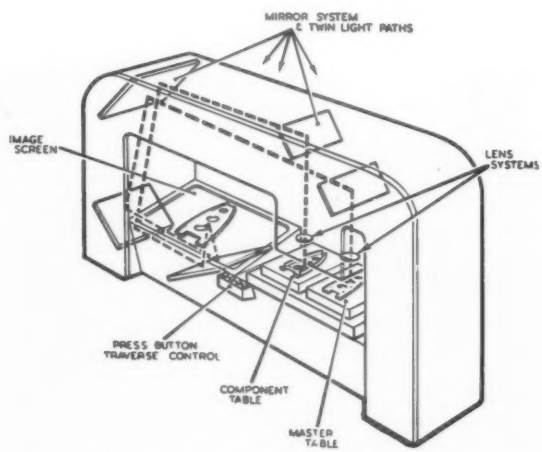


Fig. 15. An optical comparison machine

it is not possible to project the whole of the object on to the screen at one time, and the component must therefore be traversed and viewed sectionally. This is done by traversing the complete table assembly, which causes the picture to move across the screen, so bringing the whole of the component into view.

Briefly, any divergence from a master part is thrown into relief and can be rapidly interpreted and assessed by unskilled personnel.

The same thing could also be done by mechanical means. Again, both parts would be mounted side by side, and a mechanical tracer would explore those parts or profiles it is desired to inspect. Any errors on the production component would produce a varying path in the tracer, as compared with that taken by the master tracer. Any differential movement of the tracers, greater than the allowed tolerance, would cause a signal to operate, either in the form of a light, or by other means, and thus indicate that the part is outside the allowable limits.

The inspection of the many components which go to make up an aircraft assembly, which, in general, are now to closer tolerances than we have been accustomed to working, gives great scope for the development of inspection aids, any of which will pay dividends in a reduction in the number of man-hours involved in the inspection function.

Finishing of Components

The high strength light alloys which we are now using are extremely notch-sensitive, and it is therefore necessary to produce components with surfaces free from machine marks and scratches.

Formerly, components were finished by hand dressing and the use of power tools, in the form of flexible polishing equipment and polishing lathes. Such methods were extremely costly in man-hours, and it became necessary to find other methods. A solution lay in the use of the barrelling technique. By this method the components are placed in a large rubber-lined, cast iron or welded drum, together with limestone chippings, water and a foaming agent. The drum is then rotated for a period of hours, during

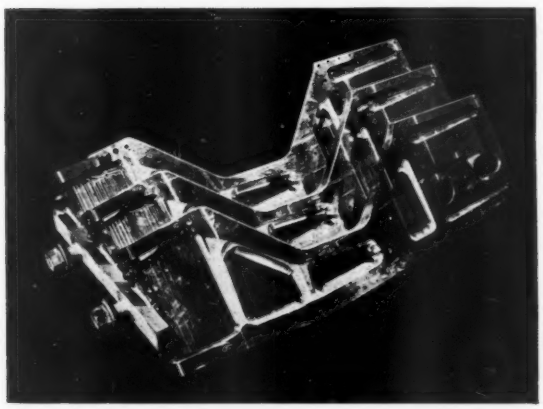


Fig. 16. Machined ribs before barrelling

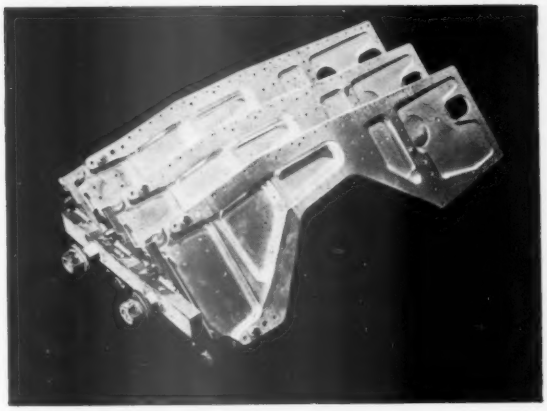


Fig. 17. Machined ribs after barrelling

which time the surface is worked upon by the chippings as they pass to and fro across the components. All machine marks are removed and a finish, better than 14 micro-inches, is consistently obtained.

The state of some machined ribs before this operation are shown in Fig. 16. Fig. 17 shows their condition after the barrelling operation.

You will notice that these large components are jigged in the machine, so that they cannot mark each other during the process. Formerly it took almost as long to complete the polishing operation as the original machining time. Components are now barrelled six at a time, and the process is completed in twelve hours. It must be remembered that this is an entirely mechanical process, in which no operator is involved during the time that the machine is working. The components shown are the largest that are processed by us in this way; the smallest weighs barely an ounce. Some 500 of the smaller components can be placed in the barrel at the same time, and the time taken to finish them is five hours.

The Vapour Blast Process

Another method of removing such marks on components is by the Vapour Blast process. In this machine the components are subjected to a jet of water under pressure, into which is injected fine abrasive particles by means of compressed air. The jet can be manipulated by means of a gun held by an operator, and any portion of the component can be worked upon to a greater or lesser extent, according to the basic surface finish. The finish obtained by this process is not so fine as that obtained by barrelling; it is around 40 micro inches, but fatigue specimens indicate that a satisfactory reduction in notch sensitivity is obtained.

The steel fittings which we use today are of 90 tons tensile and over, and a poor finish is obtained in view of this hardness. These, too, have to be polished to remove marks, but so far, owing to the unsatisfactory basic finish, and the extreme hardness of the material, barrel finishing or vapour blasting has not proved to be successful. The problem should be investigated, and electro-polishing may prove to

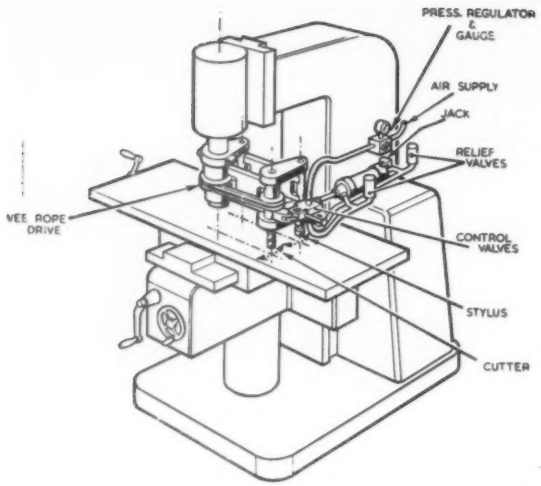


Fig. 18. Sketch of a copying device for a vertical mill

be the solution. Electro-polishing is a cathodic method of metal removal, which attacks high spots first of all, thus smoothing the surface.

But any successful method of mechanical polishing does not relieve the machine shop of the responsibility of obtaining the best possible basic finish, and there are problems to be solved here. These are to obtain better cutter life, and therefore better finish by greater rigidity of fixtures and machines, by investigation into the use of carbon dioxide as a cutter coolant, or the high pressure oil jet to the same end; better cutter grinding methods to ensure concentric cutting teeth, and elimination of grinding marks, perhaps by subsequent vapour blasting of the teeth.

Summing Up

I am concerned about the fluidity of design thought at the moment, and its effect on the future production of tools to do the job. If the future lies in titanium or steel, it is useless our obtaining expensive skin milling machines for the purpose of machining integral structures. When these are developed to the point at which they become useful tools, the need for them may have disappeared or, at best, they may have only a short production usefulness before the method is superseded. On the other hand, the production tools which we are using at the moment are going to continue to be of use to us when steel needs to be machined.

The Cincinnati Hydrotel copy milling machine is an extremely useful tool, enabling us to machine complicated profiles and contours with the use of inexpensive templates. Whatever may be the outcome of present design trends, this type of machine will always be of value.

Not everyone can afford lines of these expensive and scarce machine tools, but most factories have both vertical and horizontal mills. With a little ingenuity these can be adapted to carry out simple profiling operations.

Fig. 18 is a sketch of such a fixture. A hinged arm is fitted to a vertical milling machine spindle. At the end of the arm, driven by vee ropes from the main spindle, is the cutter spindle, geared up to enable us to take advantage of the fact that we are machining light alloys. Linked to this arm is a tracer collar which follows a steel template. A tracer is held on to the template by the pressure of an air jack. The workpiece is mounted alongside the template on the same jig, and is machined to form by movements of the swinging arm under control of the template.

Fig. 19 shows a similar arrangement for a horizontal mill.

Short Cuts and Aids

We must seek short cuts and aids to production if the costs are not to rise still further. This increase has been spectacular. In the Second World War a fighter airframe took from 4,500 to 10,000 man-hours to build. The equivalent aircraft today takes from 30,000 to 40,000 hours. I believe that we have now reached the peak in the number of man-hours taken to build an aircraft, and that with new methods we shall see a levelling off and a decline.

The increasing complexity of modern aircraft springs from development and the need to control aircraft at ever greater speeds, and to make them the finest possible machines in the present state of our knowledge. We must concentrate our production efforts on one or two aircraft only. With them, modifications must be kept to the minimum.

Complexity is the price we must pay uncomplainingly as the inevitable result of progress, but this complexity is not beyond the ingenuity of production engineers, whose task it now is, more than ever before, to introduce new labour saving techniques with the ultimate object of producing more and better aeroplanes in less time at lower costs.

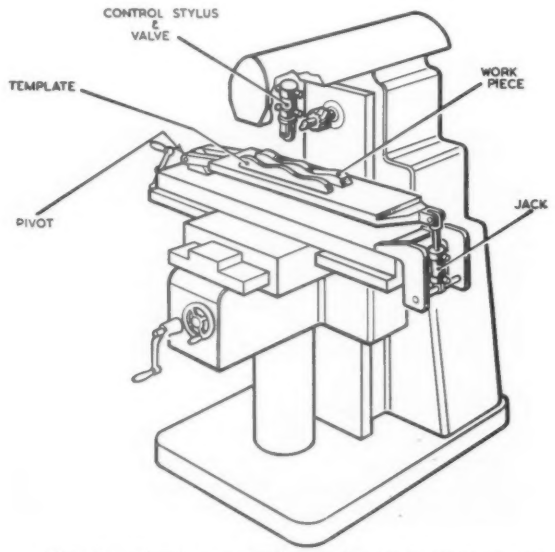


Fig. 19. Sketch of a copying device for a horizontal mill

DISCUSSION—SESSION II

Chairman: W. BROWNING, M.I.Mech.E., F.R.Ae.S., M.I.Prod.E.

Director and General Manager, Saunders-Roe Ltd.

Mr. T. Gilbertson, (*Director and General Manager, Folland Aircraft Ltd.*) congratulated Sir Roy Fedden on his excellent presentation of Mr. Dowty's Paper and Mr. Woodley on the excellence of his material. The problems arising in aircraft production, he said, could be solved by the means which Mr. Dowty himself had used to solve some of them. It would be seen that in the second paragraph of his Conclusion he stated that about 30% of his apprentices were now passing out with production engineering as their main subject. That was the right way to solve problems in the future, by investing in skill now.

Mr. Dowty had emphasised the waste of material from forgings and in the other direction had given a useful pointer to the possibility of saving materials by using zirconium and magnesium alloys. Mr. Woodley referred to the need for "close to limit" forgings. That was a matter of particular interest to Mr. Gilbertson, who thought it would go a long way towards solving some of the machining problems which faced them today. He would like to ask Mr. Woodley and Sir Roy Fedden whether in their view the aircraft firm should take over the "close to limit" forging work, or wait for the suppliers of the raw material to get down to it.

Plastics were conspicuous today by their absence, and it would be interesting to have further information about that. Was the view taken that there was no immediate future for plastics in aircraft work, and what were the complications?

Another question was whether the production development department should work separately from the experimental department, since it appeared that this was a complete field in itself and a subject which could be tackled separately.

Mr. S. P. Woodley did not think that aircraft firms could take over "close to limit" forging because of the immense duplication of plant which would be required. He did not think they could afford it, because they would all need very big die-sinking shops, which would not be economic if spread all round the industry. It was where the skill and experience lay that the forging plant should be used.

He had not touched on plastics, because he regarded that primarily as a design matter. If the designer wanted plastics, it would be possible to deal with them. Whether they would be suitable for aircraft manufacture he did not feel qualified to say, and whether they would be more economic or simpler he did not know. The only evidence he had seen that day was the drop tank shown by Mr. Keith-Lucas.

He thought that the production development department should be quite separate from anything else and directly responsible to the chief executive of the company. The personnel must be able to go to any section of the works and be completely free from routine worries. They must include a number of specialists who could be assigned to specific problems and who would stay on the job until they had mastered it. He had shown on the screen some examples of results which had been achieved by having such a department, and it had always been the responsibility of one man to undertake that specific development.

To find those men was extremely difficult. He had mentioned problems in connection with the cutting of alloy steel. The machine shop foreman knew that one always ground the tool down a little at the front and back, but not why, and they had to have some basic research on that, and not just take another tenth off and see what happened. They wanted people who were not hidebound and who would not use an old-fashioned method simply because they had been taught to employ it; they must break fresh ground. He had found people from Cranfield particularly valuable on that sort of work.

Professor J. V. Connolly, (*Professor of Aircraft Economics and Production, The College of Aeronautics, Cranfield*) said he had been particularly interested in Mr. Woodley's Paper, and felt sure that those who had not had the privilege of seeing Mr. Woodley's work at first hand would have been impressed by the vast range of new ideas which he had been able, in spite of "iron curtains" and other difficulties, to put forward, and would also realise that there were inevitably other matters which lay behind these, of an even more advanced nature. The whole approach of Mr. Woodley to this problem was extremely refreshing, because he had freely given away a large number of new ideas. It might be that other people had such ideas already, but there were a number of quite interesting developments in which those at Cranfield were very proud to have had some little part in the past, and the collaboration between Mr. Woodley and Cranfield was remarkably good.

There were so many comments which might be made that the whole of the rest of the Conference could be taken up in discussing the things which Mr. Woodley had described. It was Professor Connolly's belief, and had been his belief for many years, that progress would not take place in production engineering unless the same outlook was put into it as was already put into the design and aerodynamics and the propulsion, and weapons for that matter; and, as was well known, that was not at present the case.

Moreover, Sir Roy Fedden had pointed out what should in any case be well known, that until quite recently only a minute fraction of all the engineers who were being trained in the aircraft industry directed their attention to production, so that if one had to find production people they had to be taken from the more or less untrained class in the works, from those who had not gone through to graduate standard or to the equivalent standard in Higher National Certificate courses. Those production men who had further advanced training, so that they could do research, or had any sort of research outlook, had been in a minority.

If speed were wanted in production development the subject would have to be tackled in the well-tried way by having groups of people, a limited number of people doing much more fundamental research, and then development engineers, and thirdly the engineers who already existed in great numbers, the skilled craftsmen, the master mechanics, who, with a little guidance and some encouragement, would produce remarkable results. If they were given the guidance which Mr. Woodley outlined, and were encouraged and were told that they could machine light alloys at 5,000 feet per minute instead of a few hundred, they would go ahead, and it would be possible to harness fully the tremendous knowledge and skill of the trained craftsmen who existed in the aircraft industry already.

Reference had been made in the discussion on Mr. Keith-Lucas's Paper to titanium and to the quantities available. It might not be generally known that the American titanium programme for next year and the year

after was working up towards 25,000 tons per annum. It was known that in this country the prospects of getting 25 tons were somewhat dim.

Another question asked in that discussion was why it was not possible to obtain tapered skins. The answer was that the French aircraft industry could buy tapered skins whenever they wanted them. The "Mystère" was being built by Dassault Company with *purchased* tapered skins. If the French aircraft industry could buy them, he was worried that the British aircraft industry could not, if it wanted them. Could that be because the people making these things, were not thinking far enough ahead on matters of production development?

Sir Roy Fedden, dealing with the comments on training, said that was one of the basic matters to which correct thinking should be directed. Unfortunately, the training of production engineers was a long-term business. He had had the privilege of visiting about a dozen aircraft and engine works during the last eight months, and also a number of the older and more senior general engineering works, and had studied their respective methods of training. Although the aircraft industry, broadly speaking, had some fine apprenticeship schemes in operation and there were some executives who took training very seriously, he did not think that, by and large, the aircraft industry was giving the attention to this matter which it should.

There had been letters in the Press of late from eminent authorities about speeding up our super-priority machines, but in the past he did not think that trained production personnel had had anything like sufficient authority to bring this about. He did not want to be destructive at the present time with so many problems on hand, but he thought that to some extent this was due to the general approach of some senior executives of the companies concerned and the past policy of certain technical institutions. Technically-trained men, chief designers and chief engineers, had of late had proper consideration from a prestige point of view and were to be found on the boards of British aircraft concerns for the past ten years or more, which was a step in the right direction. But very few senior production people were on the boards of aircraft companies, and how did their prestige and background stand in comparison with that of the other sides of their firm?

He could remember the time when those who dealt with production were almost looked on as in the foreman category. That was a wrong state of affairs. In America, production technicians were properly trained and could take a degree in their subject.

That attitude existed in some of the best British traditional engineering firms which had more background and more experience on the matter, but not to the same extent, he submitted, in the aircraft industry. That was something which must receive very careful consideration. He believed it was a fine thing that production had been accepted as a main subject at Cranfield, and that something definite was being accomplished to train the right type of people.

On the question of tapered rolling, when he was working for NATO in Paris he saw the rolling work done for the Dassault Company for the "Mystère" fighter. They rolled taper sheets for wing skinning and also spars. He had sent some data on this subject to the Ministry of Supply and also to two or three firms concerned with the manufacture of light alloy sheet and extrusions, but he did not think that the matter had been very keenly followed up. Probably everybody was very busy at the time on existing super-priority aircraft which did not admit of using this technique. He felt, however, that it should be looked into, because it seemed to him to be an excellent solution, considerably better than would be seen in going around some American factories, where one was up to one's ankles in swarf from the milling operations on taper sheets for skinning wings.

Mr. R. W. Seymour-Lee, (*Chief Engineer, Western Manufacturing (Reading) Ltd.*) said he had been glad to notice that Mr. Dowty's Paper brought attention to the production of aircraft equipment, as distinct from airframes. The aim of producing aircraft must be, with a commercial aircraft, to sell it, and with a military aircraft to get it into the air for military requirements. Very expensive aircraft produced in limited quantities were obviously undesirable from both these points of view.

It had been said that it took seven years to produce an aircraft, so that even if this could be produced in one year, and it took seven years to produce the equipment to go into it, nothing would have been gained. He had no figures in front of him, but he thought the man-hours to produce an aeroplane and the man-hours needed to produce all the equipment that went into a specific type must be fairly comparable. Similarly, if figures were taken for the development of the aeroplane and for its equipment—automatic pilots, power controls, undercarriages and so on—he thought it would be found again that the figures were fairly comparable. He would say, therefore, that the terms of reference, "problems of aircraft production", legitimately covered the discussion of the bits and pieces which went into the aircraft.

He would bring all these points down to one, namely that of standardisation. With all these components, as was well brought out in Mr. Dowty's Paper, one could produce a few off very expensively to meet the requirements of one customer, and do the same for another customer, and perhaps a third time for yet another, but if it were possible to get a production run and encourage designers to use the same standard parts, production costs would be halved and the total cost of the aircraft and the time taken to get it into the air would be considerably reduced.

There were some pieces of equipment for which this could not readily be done. Undercarriages, for example, were big, and it was probably impossible to "productionise" those for different types of aircraft. Automatic pilots were largely related to the requirements of the aircraft in which they were used, since it was becoming almost impossible to produce one magic box to match the aerodynamic constants of any aircraft. Power control systems had frequency response problems to tackle, on each aircraft, so that it was difficult to make a standard unit which would fit any aeroplane. These things, however, came into the category of systems rather than components, but all systems themselves used components, so that attention might well be given to the components of systems. He would take as an example an actuator. There were a number of air, hydraulic and electric actuators, and the designer of such a component might well have the impression that the man who designed the aeroplane was not so much an aeroplane designer, as a designer of awkwardly shaped holes into which the equipment had to be fitted and where it would have to stand temperature differences of anything from 200°C. to −70°C.

Mr. Dowty's Paper showed the effort which actually lay behind the development of even a small component. If the component designer could make that effort once and for all, and produce an actuator that could be run off in large numbers, it would be very helpful. There were sometimes fifteen or twenty actuators on an aircraft, all of different types and in the next aircraft there might be a similar set again all different. The differences might sound slight to the aircraft designer, being a change of stroke of 1" or $\frac{3}{4}$" or a slight difference of stroke time, but this was often sufficient to cause the designer of the equipment to change his castings and gear ratios and force him to produce a tailor-made article. Mr. Seymour-Lee wished, therefore, to suggest to the Conference that a considerable production economy could be achieved if designers would become more "standard conscious" for all types of accessory equipment.

There was, however, a danger of overdoing it, and that could be illustrated by example, that of the electronic user who was forced by standardisation to use plugs and sockets intended for carrying heavy currents and therefore quite unsuitable for the signal voltages which he wished to use. In this case the added weight and bulk penalty completely offset the advantages of standardisation and proved very irksome to the electronic designer, who was doing his utmost to achieve minimum weight and size for his equipment.

Mr. J. Cherry, (*Senior Lecturer, The College of Aeronautics, Cranfield*) said that Mr. Woodley had mentioned that in machining high tensile steel there might be trouble due to

cutter wear, and that high-pressure lubrication would probably prove beneficial. Mr. Cherry said he would like to report on a test programme recently concluded at Cranfield on the effect of high-pressure lubrication when turning S11 steel with high-speed steel tools. They compared tool life when cutting dry with tool life when cutting with mineral oil, with the normal overhead application, and then with high-pressure application. They conducted the tests over a wide range of feeds, from .003″ to .015″, and speeds of 50 feet to 300 feet per minute.

To cut a long story short, the advantage of using high-pressure lubrication in the lower feed ranges up to .004″ was 100 times. The speed which gave a tool life of one minute when cutting with straight mineral oil and overhead application gave a life of 100 minutes with high-pressure application. The effect was not so marked in the higher feed ranges, but an advantage of about 25 times the tool life was found, so that high-pressure lubrication would probably help enormously when it came to machining the tougher steels.

Mr. W. A. Sales, (*Director of Aircraft Production Development, Ministry of Supply*), thanked Mr. Woodley for emphasising that Production Development was a real 'must'. It should, as he said, be put into the hands of people who were not tied to any particular side, i.e. "design" or "production". It would be valuable if the men engaged on this class of work had a thorough knowledge of the designer's problems as well as those of production.

Production departments were often expected to produce new designs with their existing plant and, unsupported, might not be able to make out a good case for the purchase of new machinery, but those engaged on the special work of Production Development would be able to show the need for more up-to-date plant and equipment.

Mr. Dowty deserved gratitude for what he had done to bring back cast structures into the limelight. It might not be generally realised what tremendous value there was in the new moulding techniques, in which resin bonded moulds and cores yield freely as the metal wants to shrink on cooling; the undercarriage design which had been illustrated was a very good example of what could be done on the design side by using castings. It was an important component carrying a very heavy load—a most encouraging development. Casting techniques today would provide sound complex one-piece structures in which the strength at changes of section was equal to that of a flat section, as an alternative to built-up structures in which parts were riveted or bonded together. He would make a strong plea to designers for the wider use of these techniques.

Mr. Woodley had given considerable help with regard to mechanical "finishing" processes. Scientific barrelling and high speed vapour blast had proved to be the best finishing processes available today for machined components; the latter, incidentally, providing a very useful shot peening effect, valuable in terms of fatigue resistance.

He hoped that the machine tool people would take due note of what Mr. Woodley had been doing on his own account and what was being done in other aircraft factories in the way of building special machines. In mitigation of their position, it might be, Mr. Sales said, that if the designs of aircraft from their earliest inception called for specific features such as tapered sheets and integral stiffening ribs of diminishing thickness, as in the case of the French "Mystère" aeroplane, it might be possible to get the special machines in good time for production. The French manufacturers had been able to buy a very versatile machine for their wing panels from Rigid, Switzerland, with 16 months delivery, capable not only of machining tapering skins with integral ribbing, but also (using the normal Rigid 3-dimensional hydraulic tracing gear) of contouring the junctions of spanwise and chord-wise ribs; the price being approximately half that of an American skin miller.

Mr. L. W. Rosenthal (*Co-ordinating Engineer, Saunders-Roe Limited*) mentioned that Mr. Woodley had spoken of a large forging press and had referred to it throughout in the singular. In view of the cost, would he expect that there would be only one press in the country? If not, how many could they afford, and who would allocate the priorities of production?

Another interesting point was in connection with scrap. Did Mr. Woodley get a higher amount of scrap in sterling value with machined parts than with fabricated parts? If he had a factory with nothing on the floor at all and had to produce ten ribs a day fabricated and ten machined, how much money would change hands on both systems before that production rate had been reached?

In conclusion, it was most refreshing to hear a production executive daring the designers to produce something which he could not manufacture.

Mr. Woodley remarked that although he was present as a so-called executive he was really a production engineer, and he found it very difficult and in fact highly dangerous to indulge in politics, whether company politics or national politics. In reply to the first question, he did not think one press would be enough, but equally he did not know who was going to buy one or who was going to allocate the use of it. That was a problem which would have to be worked out. If there was enough demand, he imagined that some company would provide for it.

With regard to scrap, he thought that it would be true to say, although some people might not agree with him, that the scrap which they had found with the things which he had illustrated had been far less in terms of pieces, not cost, than would occur otherwise, because with a machine such as a Hydrotel it was not possible to go very far wrong, and the scrap aspect did not worry them at all.

The third question, about what he would do with an empty floor, was a tricky one. It was not his opinion that vast sums of money were required to produce machines for the sort of thing which he had in mind. In principle he did not think that it was necessary to have 60 feet of cast iron to machine something 30 feet long, which was what was done with a planer, or a plano-mill. They had other ideas; the machine should be small and the material on a roller conveyor at each end.

Mr. A. Vines, (*Production Manager, Fairey Aviation Co. Ltd.*) said that Mr. Woodley had shown a lot of very nice ribs which were all machined to profiles. They themselves had made an attempt to make aeroplanes from the drawings, and they found that very difficult, because the present methods of lofting were still too inaccurate. With all the machine tools which Mr. Woodley used it was necessary to be very accurate, to avoid machining ribs which were beautiful but the wrong shape, and it would be interesting to know what Mr. Woodley did about accurate lofting. They themselves had developed 3-dimensional lofting to the point where they made aeroplanes to drawing so that they were all identical. That was interesting, because until then they had never made an aeroplane to a drawing, but having done so their flying characteristics were all identical.

Mr. Woodley said that it was very brave to try to make an aeroplane to drawings. With regard to lofting, when they had to produce these accurate contours he thought that the right thing to do—he was speaking of small aeroplanes—would be to make the drawing ten times full size and then reduce it photographically, thereby reducing the error. The other alternative, depending on the shape, was to generate it That would depend on the sort of sections, but probably generation would ultimately be the correct method of producing the accurate profile, while the method for small items would be to draw them ten to twenty-five times full size and reduce them, thereby reducing the error. That, however, was only a thought, and not something which they themselves had put into practice yet.

The Chairman, in closing the session, thanked Mr. Woodley and Mr. Dowty for their excellent Papers, and Sir Roy Fedden for presenting Mr. Dowty's Paper so ably at such short notice.

"USER PROBLEMS AFFECTING THE INDUSTRY"

by B. S. SHENSTONE, M.A.Sc., F.R.Ae.S., A.F.I.Ae.S.

Mr. B. S. Shenstone

Mr. Shenstone was born in Toronto, Canada, in 1906 and was educated at the University of Toronto, graduating in 1928. He obtained his Master's degree in Aeronautical Engineering in 1929.

Subsequently he joined Junkers Flugzeugwerk and Rhoen-Rossitten Gesellschaft, 1929-1931; Vickers-Armstrongs (Supermarine Works) 1931-1938; served with Air Ministry, Ministry of Aircraft Production and with British Air Commission, Washington and Dayton, 1938-1944; was appointed Technical Adviser to the Canadian Minister for Reconstruction and acted for him as Technical Administrator for Trans-Canada Airlines at Canadair, Ltd., 1944-1946; Assistant to Vice-President and General Manager of A. V. Roe, Canada, Ltd., 1946-1947; President, Soaring Association of Canada, 1946 and 1947.

He was appointed Chief Engineer of British European Airways in 1948.

THE operator of civil aircraft has special demands on the producer of these aircraft, demands which are quite different from those of the Air Force and the Navy. None of the demands is remarkable or exciting, and to an airline operator they are all obvious: in fact, they are obvious to the constructor when he is talking easily over a glass of something. The difficulty does not arise until he has put the glass aside and actually has to fulfil the obvious requirements. My colleagues and I spend most of our lives dealing with these requirements and the results of not having them fulfilled.

Practically all the operator's requirements which are special revolve about the long life of aircraft and components. It is no use saying that we require as long a life as possible: it is necessary to be precise. On the other hand, it is no use asking for the moon. We have tried it and get nothing more than a piece of cheese! So although we want an airframe to last 40,000 flying hours without dangerous fatigue, we would compromise on 30,000 hours.

I know that 30,000 hours is a great deal but I would point out that there are DC-3's existing which have flown more than 40,000 hours, and have taken about fifteen years to do it. On the other hand, we have had no such wide experience with British-built transports. No Short Empire boat did more than 16,000 hours. The old H.P.42 never flew more than 13,500 hours. The highest hours achieved by a B.E.A. Viking after seven years of operation is 10,623.

In my remarks on what I want, you will note that already compromise has come into the subject twice —the compromise on the hours and, as I have said, "dangerous fatigue". I do not expect that any manufacturer is capable of producing an aircraft which does not show fatigue of some kind. The design and production of the aircraft must be such that when fatigue starts, it can be detected and cured without catastrophe and without fantastic cost. At the present state of the art, it may be best to have wings of multi-cellular structure so that there are a large number of relatively light elements carrying the loads, the failure of any one of them not reducing the ultimate load factor more than 25%. The elements would have to be so arranged that the failure could be detected by normal inspection methods without removing wings. The same arguments are applicable to tail units.

It is quite unacceptable to suggest that a sound way out of the wing fatigue problem is so to design the spars that they can be removed and replaced at specified intervals. Any such arrangement is bound either to be extremely expensive to accomplish or, if it is cheap, the structure is practically sure to be an inefficient one. In any event, if failures are to occur, I should like to see them starting, rather than blindly remove things because they *might* fail. I might be throwing away good flying hours.

I have spoken of the aeroplane as a whole lasting a certain length of time. I mean the aeroplane *as a whole* and not just certain parts. I see no reason why any part of the aircraft should not be built to last as long as all other parts. To have to remove tailplanes at "y" hours for inspection and never have to remove the wings at all is ridiculous. The effort must be directed towards achieving an im-

provement in the tailplane so that it is as good as the wing. Practically everything I am saying is not new: in fact, consistent lives in components were written 60 or 70 years ago by Oliver Wendell Holmes, who wrote the story of "The Deacon's Masterpiece", or "The Wonderful 'One-Hoss Shay'", which was built to last for "one hundred years to a day":

"Now in building of chaises, I tell you what,
There is always *somewhere* a weakest spot.—
In hub, tire, felloe, in spring or thrill,
In panel, or crossbar, or floor, or sill,
In screw, bolt, thoroughbrace,—lurking still,
Find it somewhere you must and will,—
Above or below, or within or without,—
And that's the reason, beyond a doubt,
That a chaise *breaks down*, but doesn't *wear out*."

It is so easy to re-word this using aircraft terms that I have difficulty in preventing myself from doing so, but I will leave that to you.

I would point out that the Deacon in this poem achieved something that we have been looking for for some time, as is shown by this further quotation:–

"—for the Deacon's art
Had made it so like in every part
That there wasn't a chance for one to start
For the wheels were just as strong as the thrills
And the floor was just as strong as the sills,
And the panels just as strong as the floor,
And the whiffle-tree neither less nor more
And the back cross-bar as strong as the fore,
And spring and axle and hub encore."

In the story, this desired result is so perfectly achieved that at the age of one hundred years to a day, the shay collapsed into a pile of broken pieces. I am, of course, not suggesting that our aircraft should last quite as long or that they should come to such a sticky end, but, with the idea being so old, there can be nothing strange or odd in my demands for strictly consistent component lives. By this I mean not only overhaul lives but ultimate lives.

In this connection it is essential for the constructor at all times to study weaknesses in his work and, in this respect, people in the shop can often be of great value to the designer, because very often they know far more than he does about the actual physical attributes of the parts being manufactured. I would point out that particular things like detailed durability are very much in the hands of the production man. In one organisation, the strength of unstressable items is laid down as at least equal to the strength of the right arm of the chief designer.

During the building of prototypes, possibly the production manager could make tests of this order on his own and keep the designer informed. As it is, we often have to find out from the public at considerable loss of goodwill. I would point out that the public does not blame the manufacturer but the operator, which is grossly unfair, but somehow we do hesitate to point out the real culprit.

Interchangeability

A further demand by the operator is a degree of interchangeability unthought of by other users of aircraft. With lives of the order indicated, it will be realised that items have to be taken off and replaced literally hundreds of times and that a mere shop test that all fins will fit on every fuselage is only the beginning. The point is a practical one because in a fleet of, say, thirty aircraft, as times goes on every detachable item will eventually be fitted to every aircraft.

This requirement quite clearly means, of course, that we can have no such nonsense as instructions "to fit on the job" or "ream to fit". It must be quite clear that, if you have cut to fit the thing on the job, when every such item has been put on two or three aircraft it becomes quite useless either being full of holes or cut back so that it no longer fits. The same point goes for reaming to fit. In other words, interchangeability must have no "ifs" and "buts" to it.

Apart from the precision mentioned, the fact that items are often interchanged and must last for a long time means that all important holes must be bushed in such a manner that bushes can be replaced with ease. It is not adequate so to proportion the items that as a result of wear holes may be enlarged, since this immediately throws out interchangeability of the fleet.

I am very conscious of the fact that in the relatively short runs experienced in civil aircraft production, complete jigging becomes very expensive. Jigging such as can easily be afforded on a run of one thousand military aircraft is quite out of the question on a run of one hundred, or even less, civil aircraft. On the other hand, as I have indicated, the problem of interchangeability has qualities not met with at all on military types. There are certainly some inconsistencies in the demand by the operator and in the facilities to fulfil the demand. We have suggested, therefore, that rather than jig in the usual manner, the jig should be based on the interchangeability required by the airlines and that the problem of jigging and interchangeability should be treated as one, and at the same time the problem should be considered jointly between the manufacturer and the operator.

So far, B.E.A. has never been brought into jigging problems and we feel that, in future, it would be a good thing if we were.

As I have mentioned earlier, compromise is often necessary, and it is better to compromise with the full knowledge of the factors, and this method of co-operation on the job will enable such compromise to be made intelligently.

Consistency

By consistency I do not mean interchangeability but something less easily defined. A consistent fleet of aircraft will have almost identical performances, not only initially but during their lives. This of

course depends not only on the airframe, but also on the consistency of the engines.

In consistency I include a quality in the lives of components which is often missed. A component may have a life between overhauls of 1,000 hours. If the manufacturer is consistent, the quality will be such that the average life between overhauls, barring accidents, will be very close to the 1,000 hours. However, there are many items which, although they have a laid-down life, are so inconsistent that you cannot be sure that you can achieve the life. Such things as bearing breakdowns, electrical windings, and many other things, show that the manufacturer, once the item has passed the tests, tends to forget his standards and produces articles among which certain individuals are not inferior, but with a wide spread of quality over the lot.

My experience is that there is more consistency in articles of American manufacture than in articles of British manufacture.

Lack of consistency has plagued B.E.A., among other things, on ailerons which, although they are supposed to be identical, are, in fact, not so. In more than one type, when we change the aileron, we have to test fly it and make numerous adjustments so that the feel of the ailerons is satisfactory. This wastes a great deal of valuable time and is a direct reflection on the manufacturer.

When spares are bought over a long period, say ten years, the conditions in the factory producing them are bound to change considerably. The problem of maintaining consistency in the quality and dimensions of the spares is a severe one and, so far, I doubt if it has been tackled with enough perspective. I should be grateful if this point could be enlarged upon by those engaged in this sort of job.

Maintainability

Ease of maintenance is no original requirement, and it is just as interesting to military as to civil operators. Much has been written on it, and operators like ourselves spend a great deal of time with manufacturers on the subject. All of us still have much to learn, particularly if the maintainability is to extend throughout the life of the aircraft.

Under certain conditions, special attention has to be given to the accommodation in the aircraft for removable units. It is much easier to maintain and replace units than it is to strengthen and repair the brackets for the units in the aircraft. The same goes for access panels and doors. They must be used so often that they must be particularly sturdy, special items being hinges, latches, locks and such like items which are not usually designed for long life.

Workmanship

It is clear that when an aircraft has to last a long time, good workmanship is more important than in a short-lived aircraft. The fact that the riveting tool may cut a circle into the skin around the rivet may not affect military aircraft in any way, but it is likely to be a source of corrosion or fatigue in a long-lived aircraft.

To what extent is good workmanship bound up with good finish? A good finish is essential on civil aircraft. A good finish impresses the public and it also enables an aircraft to be kept clean and neat. In the U.K. the average finish given to an aircraft is far inferior to that given to the average American aircraft. This was very noticeable during the War and is still in many cases quite obvious. Parts and assemblies are not treated well in the shops and, in one wing factory, the impression received was that after manufacture they dragged the wings along the shop floor to get them out of the way. The resulting finish gave the impression of an extreme old age and a hard life. There is, you will admit, no excuse whatever for this and the scratches and imperfections in the skinning are all sources of infection.

Why do some British manufacturers of aircraft still find that flush riveting is too difficult and make unimpressive excuses for the use of snap-head and brazier-head rivets? There is no modern American transport with anything but flush rivets on fuselage and wing. As Heinkel pointed out before the last War, his shop people objected strongly to the use of flush riveting until he insisted on it. Whereupon they developed techniques for countersinking and control of flush rivets so that the end result was a technique just as easy to operate as the older type of riveting. The continued use of non-flush riveting on British transport makes a bad impression on the passengers and intending buyers. Aircraft with such rivets are much more difficult to keep clean.

Perhaps one of the worst aspects of workmanship in the U.K. at present is electrical wiring. It is sad to relate, but it is necessary to point out, that within the last two months an operator who bought new British transport aircraft has had to strip them of all their electrical wiring and renew it, before they could put this type into operation. This is a terrible slap in the face and something that will not remain unknown because the operator is so fed-up at having to do this job that it will become widely known.

I will say no more about workmanship except that a reputation has been built up for British workmanship and it is about time we stopped living on that reputation.

Sense of Proportion

It is obvious that an aircraft operation can easily be a dangerous business. The fact that it is not particularly dangerous is the result of constant effort on the part of all concerned. The manufacturer and the operator are two of the important factors in this fight against danger. We all know that the only way to guarantee that an aircraft will never crash is to ensure that it never flies, and if we are not careful some of the technical standards which we build up will tend to keep the aircraft on the ground unnecessarily. In other words, we have to develop a sense of proportion and this comes down to a long series of decisions regarding the ability of an aircraft to fly safely. Quite often the factors to be considered do not allow an easy and clear-cut decision. If the decision is too often too lenient, operational safety

may suffer and the passenger will feel, and rightly, that flying is dangerous. If the decisions are taken too rigidly and aircraft which could fly, would not fly, the prospective passenger would feel that flying must be dangerous because it is not dependable, or he would merely think that aircraft have been badly developed and that he should keep away from them.

Obviously, the real answer is the middle way, which produces the maximum possible reliability with the minimum danger. It is not possible to lay down hard and fast rules for this. It is of course almost entirely a matter of experience and confidence, and much of this has to be built up between the operator and manufacturer. When a fault is discovered which obviously must be cured but its immediate effect on the safety of operation is unknown and unknowable, it has been the tendency for manufacturers to take the easy way for themselves and leave the hard way for the operator.

It is too easy for the manufacturers to say: "We have found that so-and-so may be wrong and therefore please do not fly again until we put it right on all the aircraft we have built". To come to such a decision it is necessary to devote very little thought to the problem. It is far better to devote much more thought to the problem and to advise the operator fully of the pros and cons, assisting the operator to come to a technical appreciation of the trouble. Often to play safe is to make flying seem more dangerous.

Timing

If all the problems I have mentioned are solved, yet are not solved at the right time, they are not solved at all. The aircraft operator has to work to a schedule. If you promise to deliver an aircraft at a certain date, you should expect to be believed and expect to fulfil that promise. If you are believed and do not fulfil that promise, the results can be disastrous because the airline will probably have sold the seats shortly after the promised date of delivery, and will reap a tremendous amount of ill-will which will not be fully passed on to the manufacturer. If, on the other hand, the airline does not believe the manufacturer but he still produces the aircraft on time, the operator will lose money because he has not sold the seats. The only answer to this is for the operator to have a basis for confidence in the promises of the manufacturer.

This necessity for timing does not only apply to initial manufacture but to the delivery of spares, to the turn-round of aircraft sent in for modification, and the overhaul of equipment sent to the manufacturer.

I would like to say here that no airline likes to send equipment, including engines, back to the manufacturer for overhaul. For one thing, it slips out of his control and he does not know in detail the troubles that occur and how they can be put right. The operator has no sympathy with the manufacturer who tries to persuade him that only the manufacturer is capable of overhauling his product. To insist on that is, in my opinion, no more than an admission that the product is improperly designed. I would say that, as far as I know, no equipment has been so improperly designed that an airline cannot overhaul it as well as or better than the manufacturer.

It may be worthwhile warning manufacturers that the more they insist on the necessity for them doing the overhaul, the worse is the impression made on the operator. If the manufacturer did actually insist on overhauling his own product, it would be quite sufficient reason for me not to use the product at all, but to find an alternative.

Summary

Most of what I have said revolves around the long lives that we must have in airline work. The aircraft must last a long time. Items must be interchanged again and again for many years. As items wear out, new items consistent with the old must be bought and used. Indeed the operator's job is one of constant repetition over a much longer period that that met with in any other aspects of aviation.

Such are the civil operator's problems and they are very real, and many of them need more action than they have received to date.

DISCUSSION—SESSION I (*continued from page* 92)

problems involved in production, and it was this fundamental grasp that led to the machine tool as it was known today.

The Chairman, in closing the discussion, said that the Conference had been given a good start. It would almost appear that production engineers had no troubles, except that they were short of money. So far as being able to make the "bits and pieces" was concerned, it could only be assumed that their silence meant assent and that there were no longer any difficulties in the actual making of the aeroplane. Who was going to provide all the money which was wanted was not clear, but it seemed fairly obvious that someone had to do so. In America four years ago they had complete wings, two years ago they had such wings made in large numbers, and now it was almost standard practice. He would not go so far as to say that this country had done nothing about it at all; a fair amount was being done, and he thought that in time there would be a great deal more. He had no doubt that by one means or another, on which he would not comment at the moment, someone would find the money. If when saying that he happened to be looking at a representative of the Ministry of Supply, that was quite accidental

Everyone would wish him to express to Mr. Keith-Lucas their appreciation of the trouble he had taken in preparing his Paper and of the really masterly fashion in which he had presented it. (*Applause.*)

"USER PROBLEMS AFFECTING THE INDUSTRY"

by AIR MARSHAL SIR R. OWEN JONES, K.B.E., C.B., A.F.C.

Air Marshal Sir R. Owen Jones

Air Marshal Jones was educated in Engineering at the Manchester College of Technology (combining the course with a short apprenticeship in instrument making) and later at Cambridge where he took the Mechanical Sciences Tripos. After Cambridge he did the post-graduate course in Aeronautics at Imperial College.

The Air Marshal started his R.A.F. career in 1924 and alternated flying duty with technical duty. The latter included the command of workshops on aircraft maintenance and overhaul, several years at Farnborough on instrument design, development and testing, a period as an Overseer in the aircraft industry, and some time on the training of airmen and R.A.F. apprentices.

Most of the last War he spent with the Ministry of Aircraft Production, finally becoming Deputy Controller of Research and Development. He is now the Controller of Engineering and Equipment at the Air Ministry.

I DO not think it possible that there is any customer of the aircraft industry who can be more annoying to the production engineer than the Royal Air Force. No sooner do we settle our requirements (after long cogitation) and see the designs progress to the jigging and tooling stage than we change our minds, turn all your work-flow charts into confetti and put you production engineers one step nearer the mad-house. We are not alone in this, I believe. I have heard that your own designers are also responsible on occasions for a grey hair or two! You are, however, kind and understanding people, tolerant to a fault, and forgiving of nature, always well able to realise that we, too, have our problems, so all is forgiven. Well, eventually we reach a decent understanding on the design, everyone rolls up his sleeves and gets down to it, and then the fat is in the fire again, for we then demand a doubling of output, deliveries to commence six months ago. A few months later when everything looks as if it is going to flow smoothly and the dawn is at last breaking we cut the order by 50% and chaos once more reigns!

All that, of course, is a grossly exaggerated (I hope) picture but one with a grain of truth in it. However, as I said before, you are a kind and understanding people, and realise that, although we make occasional slips, the great majority of our apparent eccentricities are the results of outside pressure coming from three main sources—the researcher, the enemy, and the Chancellor. The researcher always seems to bob up with a better idea the moment we have got our teeth into his last effort, the enemy refuses at times to conform to our plans and the Chancellor is always with us. We are, therefore, between three fires, and must be forgiven for jumping about occasionally like singed cats.

My colleague, Mr. Shenstone, has given you his side of the picture and I often sit back and envy him his steady operating schedules, his set routes, his predictable loads, his long-service maintenance crews and his consequent ability confidently to plan ahead. The conditions of operation of Royal Air Force aircraft and equipment are vastly different, and it is in connection with these differing factors that there occur a number of points in which production matters have a direct impact on users.

Servicing Stages and Methods

To give you, if such is necessary, a picture of the background to our operations and the conditions under which they are carried out, I propose briefly to outline our servicing stages and methods, taking for my example a typical fighter station. What we call first line servicing takes place at the aircraft wherever it may be, on the tarmac outside the hangar, away at dispersal on the other side of the airfield, or even at another airfield where operations have demanded that it shall land. It consists of refuelling, rearming, refilling with oxygen, replenishment with starter cartridges and so forth, but with only the simplest of checks on tyres, controls and equipment unless some fault is reported by the crew. In that event rectification is attempted on the spot by adjustment, by the use of simple test gear and by simple replacement. If the fault is not remediable in the open air by these simple means the aircraft goes back to the hangar for further investigation. You will see quite clearly that these conditions demand good accessibility, facilities for high speed replacement and the general configuration which will allow for quick turn-round. These points are generally so obvious that they are usually well catered for.

Second-line Servicing

What we call second-line servicing takes place in a hangar and its annexes and it is to this process that I wish to draw particular attention, since it is mainly in this phase that the 'awkwardnesses' of an aircraft are most manifest. Second-line servicing is usually done on a Station basis, that is, one Technical Wing looks after two or three Squadrons operating the same type of aircraft. The hangar I have mentioned is not always heated but is reasonably well lighted. Attached to it are heated and well-lighted annexes which we call 'servicing bays' and which deal, in a typical fighter case, with tyres, electrics, radio, armament, hydraulics and oxygen, etc. etc., each in its own bay. The main work carried out during second-line servicing in the Technical Wing is inspection, rectifications and modifications.

Third and fourth-line servicing require facilities and test gear which are not held at Stations and they are therefore done at bases in Maintenance Command or in your own factories.

Having now given you, I hope, an idea of our work and the conditions under which it is carried out, I would like to draw your attention to some of the directions in which I think the production engineers can help us to keep the maximum number of aircraft in the air. It is within the power of the designer, of course, to do most in this direction and he responds well to our requirements although it must be often very irritating for him so to do. Not only has he A.P.970 cramping his style, but we also send liaison officers to your factories and follow them up by our people from the Central Servicing Development Unit, who are preparing the instructions and schedules which will govern the servicing when the new aircraft comes into the R.A.F. They also are for ever pressing the need for easy servicing. So the designer is under heavy pressure and I won't add to it. Moreover, at both this Conference and that of last year you have devoted much time to this very aspect. I will therefore pass straight on to those problems which more directly affect the production engineer, of which the first and greatest is 'modifications'.

The Modification Situation

The modification situation has changed very considerably of recent years. We have a far more complicated aircraft to deal with, more equipment inside it and a new type of power installation with its attendant new equipment. We have the pressure of almost war to urge us on but are without the priorities and facilities which war itself would give us. Added to all this, complicating and enlarging it, is the fact that nowadays almost everything is ordered "off the drawingboard". This is a fine concept, and I never would advocate a return to the old procedures of building an aircraft and improving it before buying it in quantity. Adding two or three years to the development life of an aircraft in these dangerous days would be suicidal.

But there is no getting away from it, ordering off the drawingboard does throw an enormous work load on to the Services in respect of modifications, the need for which is not apparent from the drawings, but become very obvious as soon as production and flying start. We are doing our best to help to discover what needs doing to an aircraft "off the drawingboard". As well as the Boscombe Down trials, we now conduct, on our first deliveries, "intensive flying trials" during which we get 1,000 hours flying on eight aircraft in the shortest possible time. This has been most valuable up to date and will be continued, but much of the value is lost if early deliveries are not fully complete aircraft. You may be surprised to hear that a new type of single seater coming into service can have as much as 800 man-hours of B.2 modification work per aircraft outstanding on delivery, with the certainty of many more hundreds of man-hours to come as the months go by—all to be done, not in the factory, but under conditions such as I have described. This initial load is not the only trouble. As you are well aware we are short of advanced tradesmen in certain trades, and an initial handicap can easily develop into a permanent backlog, particularly when we cannot spare aircraft from the front line and from training for modification incorporation in industry. The longer modifications pile up the less fit our aircraft are and the more modification sets there are waiting on the shelf, to the detriment of the taxpayer's pocket.

Building In Modifications

In the Royal Air Force we aim to incorporate modifications in second or third-line so that the aircraft are not far away in the event of emergency; but a peak load of modifications is a problem, particularly as it falls at the time of the introduction of a new type which pilots are keen to fly, and which ground crews are keen to explore so that they can service it properly.

May I plead, therefore, that these modifications shall be built into the production aircraft as soon as it is humanly or super-humanly possible. The results of such a course are clearly a more potent Air Force at an earlier date, at less cost to the taxpayer, and those are benefits well worth striving for.

I would ask for similar efforts also in the later life of the aircraft. Every time you can incorporate a modification at an earlier rudder number, you are giving us a better equipped front line at a cheaper cost to the nation, for it is clearly more efficient and less costly to incorporate in production, than to tear down and incorporate after delivery. Apart from that we are reducing the effective front line while the job is being done.

I have stressed the modification point and I am sure that many of you are thinking, as I have often thought—"Is your modification really necessary?" Three times in the past seven years high power committees have sat to explore this very point and have emerged with suggestions which have been put into effect. The filters now in the modification pipeline are, in my opinion, efficient, but in order to put the matter to the test we recently had a census of opinion as to whether all modifications were

necessary. We asked the Squadrons in all Commands their opinion; 1,100 modifications were surveyed and doubt was cast on only three of them; moreover, in no case was the doubt unanimous among the users in two or more Commands. I don't intend to convey that I am satisfied that our efforts have produced a system good for all time. We shall quite conceivably set a fresh committee onto the problem before a year is out and overhaul our filters again.

Modifications are a headache to everyone, but there is one aspect I would like you to ponder before thinking too hardly of them. They are, after all, the physical manifestation of the development of an aircraft type. A new idea, a new necessity, comes up and is embodied as a modification. It is there for all to see and all to judge. If it passes judgement it becomes a part of the thereby improved aircraft and passes on to the next generation.

On the other hand, if we had no modifications new ideas would be untested, new potentialities unexplored and the next generation the poorer for it.

Importance of Spares

The second major sphere in which the production engineer can give the user a helping hand is in connection with spares. I know I am harping on a very hackneyed theme and one of which you are probably very sick, but spares are literally our lifeblood; without them the finest Air Force in the world is impotent and its cost thrown to the winds. It distresses me beyond measure to see aircraft costing thousands and thousands of pounds lying immobile for the lack of a spare costing only £5 or £10. Those of you who deal with repair contracts will know exactly what I feel.

This business of spares has haunted me ever since I became responsible for them just over a year ago. I have concentrated a very large portion of my time during that year to the study of the R.A.F. provisioning methods in an endeavour, firstly, to be sure we ask for what we need in the quantities we need and, secondly, that we don't ask for too much to the detriment of the taxpayers' pocket.

In the first instance my people get together with the firm to judge to the best of their combined ability what maintenance spares will be required for a new type. Quite recently this survey has been extended to cover repair spares. The maintenance spares should come along with the first aircraft and should then match in predetermined manner the subsequent production. I very much regret to say that in no aircraft instance have we had those spares 100% on the nail. Quite recently I told a certain manufacturer that he would make aviation history if all the due spares arrived on the due date. It wasn't a terribly difficult proposition and he nearly made it. He produced 93% on the due date. I am still waiting for the 100%!

Those initial spares are of immense importance to us as are test equipment and ground handling gear, and in deciding what we need we are all in somewhat unknown territory, but when we have decided what is needed, may I plead for them to come forward so that we can deploy them with the aircraft. Nothing is more discouraging to our young pilots and our servicing crews than to have lovely new aircraft grounded for lack of spares.

Reconditioning Problems

We do not finish with our spares troubles when they are in full production alongside the aircraft, but come up against a further problem when our aircraft are seriously damaged, as, for instance, in a belly-landing, or when elderly aircraft come to reconditioning time. In all probability, by that time production has ceased, your tools have been put aside and your floor-space and energies switched to a new type. Then a belly-landing or a reconditioning call for spares which have never before been demanded. Personally I know what it means to reorder material which is out of production, dig out dies and fit them back into presses, to set up complicated machining processes anew, to re-erect jigs and perhaps to retrain labour or divert highly skilled men. But many of my colleagues do not and many a struggle have I had to restrain them from impossible requests.

But, without that awkward bit the aircraft remains on the ground—locked-up capital—a liability instead of an asset. May I implore you again, therefore, to do your very best to produce for us that odd spare, the necessity for which has been foreseen by no one. In this connection, a short while ago, Sir Frederick Handley Page brought to my notice an article in an American technical journal dealing with this very subject. In anticipation of this unforecastable demand arising after normal production had ceased, one firm had made a special study of the disposal and storage of the tools from the old production line with a view to the most efficient and speedy production of a few off when the demand arose. To this they allied an organisation for manufacture which they called the "short-order shop". To these schemes they credited very considerable saving of time in turning round repair jobs and I have no doubt whatever that the American Air Force gladly welcomes the consequent improvement in the ratio between time serviceable and time unserviceable.

I now wish to speak of some more minor problems than those of modification and spares but which occasionally are very real problems to us. In so doing, I shall find myself compelled to make suggestions as to how they may be met, suggestions which may be considered really to be outside my sphere but I hope that they will be taken as constructive suggestions, which they genuinely are intended to be.

Interchangeability

We still get isolated instances of lack of interchangeabality. I need not detail to you the troubles that it brings in its train. Provisioning, manufacture and distribution of spares is difficult enough, but to have to duplicate the process is always disheartening and sometimes critical in regard to our operations. A strange incident occurred recently which I think must have been due to lack of interchangeability. I was handed several bolts which had been taken from

an aircraft main joint. The bolts had been reduced in diameter by filing or grinding and had been tapered at the top to provide a lead in. I do not think that the workman concerned had intended to leave the bolts in, but had used them to pull the joint straight and then forgotten to replace them with whole bolts. There is no question, however, that there was a danger to life and in my diagnosis it was primarily due to non-interchangeability.

Accessibility

We still get cases of inaccessibility for servicing purposes, despite the precautions I mentioned earlier which are taken during the design stage. It is difficult to see how these creep in, but I think that there are two possibilities on which you production engineers can have a beneficent influence. In the first place you are the first people to see the final job in three-dimensions—all our early precautions are taken on the drawingboard in two-dimensions and it is not easy to see, in two-dimensions, how a man's hand, perhaps with a spanner in it, is going to be operable in a confined space. If you could have the servicing aspect at the back of your minds while you are building, you might well be able to set the drawing office right at an early stage and help us a great deal.

Secondly, I have an idea that you may, on occasions, suggest to the drawing office a slight change in order to help with the easier fabrication of a part. It is possible that the feature which you don't like has been incorporated, in the first instance, to ease servicing, and when you ask for a change the drawing office has not recalled exactly why it was originally drawn that way. If you could check on the servicing aspect before suggesting alterations, I think it might help us considerably. We have in two or three instances in recent years had to introduce special tools for servicing where I am sure the original design was careful to avoid that very thing.

New Fabrication Techniques

Repair work within the Royal Air Force these days is coming up against two new deterrent factors. Firstly, the increased thickness of plating and, secondly, the new techniques used in aircraft construction. Shortly, we shall be unable to replace a damaged piece of skin in the field because we shall need power tools to do the dimpling for the rivets, while the new stretching techniques and the like militate against repair since the component cannot be broken down for access. I know that high speeds demand high strength and I know that strength cannot be obtained at a reasonable weight without some of these new techniques, so here we are between the devil and the deep sea. The only answer is more spares and facilities for rapid replacement.

But while I am on the subject of new techniques could I plead for the development of new riveting techniques. We are getting an inordinate rise in the number of loose and broken rivets in aircraft. It does not appear that joints are badly designed but I do suspect something wrong with riveting procedures, since associated with failing rivets we so often see undue dolly marks on the reverse face, or it may be that the rivets have not been conditioned to the requirements of their materials. I don't think the present blind riveting methods we have had so long are up to present-day demands. The differing varieties of blind rivet fail too often for peace of mind.

Stress Concentration

It is hard to believe, but we still get aircraft structures starting cracks at sharp corners. This can't be ignorance, since every junior draughtsman knows the importance of the rounded corner and the generous fillet. I think the trouble again arises through the drawing office seeing things only in two-dimensions. You who first see the thing in three-dimensions, as I have said before, can spot what others may miss. Please keep an eye open and refer back anything you may judge to be 'sharp' practice. It will help us to avoid modifications and may save a life.

Inspection

We occasionally get examples of defective material or defective workmanship which have been missed by the eagle eye of the inspector. I know how keen you all are about the declaration of defective work—the notices in your factories speak for themselves—but I think that often enough your homilies are addressed primarily to the man who makes the mistake. Might I suggest that everyone be encouraged to look out for mistakes or defects and to declare them; in other words, to encourage everyone to be an inspector. There may be no problem in respect of the reporting of defective material, but there may be difficulty in getting Bill to report Jack's bad workmanship. However, that is your problem as practical psychologists and not mine, thank goodness!

In a batch of recently delivered equipment, we came across a series of defects which were quite new in our experience and appeared to be the result of a new method of production. They had all slipped by inspection and I couldn't understand why. When I made enquiries I found that these particular articles were inspected on a mass-production basis, each examiner examining for one fault. When the unexpected fault cropped up there was no examiner to catch it, so we caught it, literally! There is a lesson here, not necessarily for airframe and engine people, but definitely to be pondered over, in my opinion, by those responsible for quantity production of the smaller equipments.

Production

So far I have been talking about hardware but before I finish I would like to put before you one or two factors which arise in connection with production programmes and their fulfilment. When production runs late on forecast, we, the users, are faced with a variety of problems, often very embarrassing and often very costly to solve.

Re-equipment plans of the R.A.F. are bound up so closely with production that all supplementary plans for the provision of trained manpower, airfields, installations, special-to-type equipment and domestic accommodation have to be geared to the forecast aircraft programme, in order that we can be ready to re-equip as new aircraft come off the production line. If production is late the following are among the user problems arising. Specially trained Service personnel may have to remain idle or have to be dispersed with consequent difficulty, cost and upheaval in re-assembling them. Pilots already converted to the new type may have to go back to an old type with consequent loss of morale and enthusiasm. Reprovision for the continued spares support of an obsolescent type cannot always be arranged at short notice if a production line for spares has already been closed down and, finally, we may be faced with heavy costs for reconditioning the old type when we were expecting to relegate it to obsolescence. My points apply not only to the airframe and engine but also to the equipment they carry. Delay in equipment availability reduces the effectiveness of the front-line, so it is vital to get the maximum co-ordination between the aircraft and its fighting gear.

All this sounds as if, in my belief, you didn't realise the importance of production programmes. I know that you do realise that importance and that you have great incentives to meet the programmes, but I thought it would not be amiss to show you the picture as it affects the Service.

Conclusion

During the course of my survey of our problems I have made suggestions on relationships between design, production and inspection which may have sounded rather like unwarranted dabbling in something which is not my business and which, in any event, is running quite nicely, thank you. I do assure you that all my suggestions have been designed to be constructive and that I believe that there cannot be too much interaction between the elements I have detailed. I would go even further and say that within the production machine itself, interest and co-operation between different sections can be fostered to great advantage. If, for instance, those engaged on component manufacture are given the chance to see the main assembly line and are shown where their bit does its job, their interest and consequent efficiency can be greatly enhanced. We do this in our repair Depots with the young National Servicemen and find that it pays hands down.

In the course of the last half-hour I have told you of some of our troubles and have asked you for a great deal: more production, earlier incorporation of modifications, earlier spares together with a number of other incompatibles, and I am sure that you are thinking: " Here is the R.A.F. again wanting its cake while it eats it and demanding quarts out of pint-pots." How right you are, and what a normal problem in catering for the R.A.F. but I am sure, judging from past performance, that if anyone can produce that impossible meal, it is the production engineers in this country.

DISCUSSION—SESSION III

Chairman: F. C. COOKE, M.I.Prod.E.,

President, Southern Section

Wing Commander L. P. Gibson, (*Technical Branch, R.A.F.*) said that after two such excellent Papers there was very little he could criticise, and indeed it would be presumptuous on his part to attempt to do so. He wished, however, to introduce a word which had hardly been used at all during the Conference, and that was the word 'War'. After all, military aircraft were designed and produced in large numbers to cope with the rough-and-tumble and robustness of war. For the past few years there had been annual air displays at Farnborough, with the aircraft in their scintillating colours and multifarious shapes, set in a framework of coloured caravans. The effect was almost like a picture by Matisse. The fact had to be faced, however, that military aircraft would have to be used in war.

He knew it was both dangerous and imprudent to draw conclusions from the last War, but he thought one would be on fairly safe ground in anticipating that, in war, one of the foremost problems would be increased range. There had been very few aircraft ever built, apart from trainers, which had not required more fuel. That problem would have to be faced by designers and producers, by putting fuel inside the aircraft, refuelling in the air, or putting it on the outside, as in the case of drop tanks. Mr. Keith-Lucas had referred to making drop tanks of a new and cheap material. Drop tanks, as their name implied, were meant to be dropped. In the last War, one type of fighter alone used up 300,000 drop tanks. It was no use making drop tanks of an expensive and strategic material if they were going to be expended in vast quantities.

Another problem with which they would be faced concerned the airfields. The position might be satisfactory in this country now with its vast stretches of concrete but these new aircraft, with their greater weights and higher tyre pressures were making, both literally and metaphorically, big inroads into the concrete. And concrete, both in war and peace, was in short supply. This might lead to the problem of shorter take-offs with rockets, accelerators and the like. There would also be the problem of shorter landing runs with braking parachutes and the various braking devices. Even the reserve of energy in the engine might help to stop the aircraft. Those were the main problems of take-off and landing.

In the air, there was always the demand for more fire power and greater bomb loads. In the last War, the weight of one fighter had gone up from 5,000 lb. to 10,000 lb. That put an enormous load on the design and production engineers in the industry.

Another important problem in war would be that of vulnerability and survival. The philosophy of design for survival in the Western hemisphere was different from that of the East. We must design for survival and the problem would not change in the next two or three decades. The problem would be very real in war—how to get out in the air, on the land, and in the water. Many times in the last War it had been said: "I saw only two or three out of a crew of eight getting out." That thought might be borne in mind during the design and production stages. Another problem was that of fire, which also became apparent in war. There was now a most unfortunate juxtaposition of more and more fuel with more and more heat in the engines, the unfortunate crew being close to it.

Probably some conclusions could be drawn from the war in Korea, and no doubt in time those lessons would trickle through. For example, he did not know how the axial flow engine had behaved in war and whether it had shown itself to be fragile or not. All these were very real problems which no doubt would, as usual, be sorted out and solved by that very understanding body, the designers and producers in the aircraft industry.

Professor J. V. Connolly, (*Professor of Aircraft Economics and Production, The College of Aeronautics, Cranfield*) suggested that the Conference had missed an opportunity which some of those attending it had thought that it would try to take, and which had been envisaged in the penultimate paragraph of both the Papers now under discussion; namely, to talk about the real problem of production appropriate to the level of the Conference; the problem of getting the right aircraft at the right time. The details—the machine tools and the jigs and so on—were not really the problem which high-level production people should be considering in conference. Both Sir Owen Jones's men and Mr. Shenstone's men came to the aircraft works and stuffed down the throats of designers at all levels the things about which they had been speaking that morning, and did so in detail, with plenty of time to deal with them, and in a way which was much more effective than talking about them as generalities, as they must be talked about in such a Conference as the present one.

Professor Connolly had certain theories about the question of time which seemed to him to be more important than dealing with the details of modifications. If one could get an aeroplane into the air in four or five years, instead of about seven years which it took at present, one could afford to "muck about" with the modifications a little longer and still be better off. This period of six or seven years was not a new one. He recalled that the big bombers, and some pre-war aircraft of the fighter class, took about that time to get into service. In the War, however, he well remembered one not inconsiderable aeroplane which had been designed and was flying inside a year; he referred to the Mosquito and, for that matter, there was also the Meteor. Those two aircraft had been so far ahead of their competitors that one could afford to take short cuts, and not to put the design time into the details, but to allow that sort of thing to emerge in the process of absorption into the Service. The net result of that had been a cheaper aircraft project and a more advanced aircraft in the squadrons and not many modifications. Since time was of the essence of the whole of this business, he thought that the Conference ought to have taken up at an earlier stage the point made by Mr. Vines and by Mr. Woodley as a major theme, namely how to cut off three, four or even five years from the time at present occupied.

It was known from experience that there was a tendency, without going into detail, for the Americans to clip about a year off the time taken in this country.* That gave them a lead and, if any little snags did come up, they would be working on something which was in existence already, and not on something theoretical. It was not possible to go into details but, since the Conference had not spontaneously discussed this matter, it seemed to him to indicate either that there was a lack of appreciation of the importance of this problem, or that the production engineers who attended the Conference had a lack of confidence in their ability to speed things up. He would like to hear what the authors of the two Papers had to say on the need for concentrating attention on a major improvement in the time factor.

He would like to recall what he himself always called the "Shenstone Law", though Mr. Shenstone might have forgotten it, and that was that 'the utility or the weight of an aircraft was inversely proportional to the length of time which it took to build'. Mr. Shenstone facetiously proved this before the last War with figures showing how the structure weight always increased with time. That applied to many other things in the aircraft. It seemed desirable to re-examine the Mosquito and see what happened in the case of that aircraft. There had been plenty of changes of Mark Number, which finally went up to 42, but the *compulsory* modifications which had been necessary to make it a good aeroplane had certainly not been outstandingly greater than those required in other aircraft with a much longer development time.

Air Marshal Sir Owen Jones agreed with what had been said about the development time, which was getting truly elephantine, but suggested that it was the designers rather than the users who should discuss this subject. The users wanted their aircraft quicker, and it was the designers who might be able to provide them more quickly. He would remind Professor Connolly, however, that the Mosquito had been unique in being a wooden aircraft.

Mr. B. S. Shenstone, dealing with the problem of getting aircraft more quickly, said he still agreed with his pre-war theory that the longer it took to build an aircraft, and particularly a prototype, the heavier it was, because it meant that people had more time to think up things, and it gave the Air Force and everybody else more chance to get things in before the aircraft was built. In other words, it illustrated the opposition between the manufacturer and the Air Force. Sir Owen Jones wanted the modifications before he got the aircraft, while the manufacturer wanted to produce the aircraft as quickly as possible, and it was not feasible to do both.

With regard to civil aircraft, there was a danger in using an aircraft which to the non-technical person looked satisfactory, but which the technical person realised was imperfect. It was quite easy to produce a civil aircraft more quickly than was the case at present, with engines of inadequate development and fuel pumps which had not suffiiciently fine tolerances and so on. To the non-technical person it might look very good, and they would tend to say "Don't let it stand about; put the passengers in it"; but that would be dangerous, because it would get a bad name for being unreliable, and it would take some years to build up its lost reputation. He was against, therefore, putting a machine into service which was under-developed, because it meant bringing down on oneself an avalanche of trouble.

What it came to was that one was getting together a big box of tricks. It was not simply the aircraft manufacturer who was concerned, particularly in the case of complex civil aircraft, but dozens of manufacturers who were producing often relatively new articles, all to be put inside one box. For them all to be satisfactory straight away would be a miracle, and miracles did not happen and must not be expected.

Sir Owen Jones seemed to think that the air line operator had a quiet life. It was all very well to say that the distance from *A* to *B* was always the same, and that the civil air line operator was always going from *A* to *B*. The fact was that even the distance between London and Paris was not constant, but changed according to the arrangements made by those in control of air traffic. Sometimes it was necessary to fly as far as Norfolk before being allowed to make for Paris. There were other difficulties which affected the air line planner. For instance, the

Speaker's Note

* *This was correct during the War and after all "Sabres" are in use in quantity and so are the large jet bombers!*

Russians had made it impossible for B.E.A. to fly to Prague, but the Russians had also made it possible for them to make money on the Berlin route because, having isolated Berlin, B.E.A. were making money by taking Germans out of it.

Mr. R. E. Mills (*Senior Designer, Bristol Aeroplane Co., Ltd.*) said he would like to tell both speakers that, whilst appreciating that the customer was always right, the aircraft manufacturers were not so bad as they had been made out to be. Mr. Shenstone had referred to the question of tolerances. Any design or manufacturing team which was worth its salt looked on tolerances in the same way as Mr. Shenstone did. They were a necessary evil. No one would make something to 0.0001″ if he could made it within 0.005″. He could give an instance in connection with B.E.A. His company had a certain unit in which they had a 0.025″ clearance. B.E.A. wanted a much higher performance from that item than it had been designed for originally, and his company had found, as they had suspected, that by reducing their tolerances to 0.005″ instead of 0.025″ they could give B.E.A. what had been asked for with no increase in weight. Reducing this particular tolerance to 0.005″ meant, on about a dozen components, reducing tolerances to fractions of a thousandth of an inch. They had to have those small tolerances, and were proud to be able to maintain them, but they did not want them.

There was an old problem on which Mr. Mills would like some further information. Various guesses had been made at the value in £ s. d. of one pound in weight of aircraft. He had seen a Paper not long ago in which the value had been stated in one part of the Paper as £65 and in another as £300! He thought that the value per pound was a very useful guide in design and in manufacture, assuming, of course, that there was a fairly good standard of design and of manufacture. One would know how far one could go on one's design and on the finish which could be produced on a component if one knew that figure. He would like to know whether the two authors could give a "guesstimate" of its value.

Air Marshal Sir Owen Jones said that the question of cost per pound weight was one which he had not personally studied very much. He had read about it, but in relation to civil aircraft, and the only figure which he could recall was that of 1,000 dollars per lb. weight, which had been given in an American Paper, and was over a life of ten years. The figure had not been calculated on military aircraft, because the cost in pounds sterling in relation to military results was an almost impossible figure at which to arrive; it was like the old arithmetical problem of equating the cows and the sheep. It did not work out in pounds sterling, because there were things on the military side which could be reckoned in £ s. d. Mr. Shenstone should therefore have a better background for answering the question.

He would like to say a word on tolerances, a question originally raised by Mr. Shenstone. There were places, he thought, where it was possible to do a little too much fine engineering. One of the places where that came out very noticeably, particularly on jet types, which were now very low to the ground because the propeller had gone, was in the undercarriage and undercarriage door mechanisms. These must work every time, or there would be an expensive repair on an expensive aircraft and the aircraft would be out of action. In order to make them work every time there was a tendency to make the finest engineering job possible at those points, but he himself believed that a certain ruggedness there might pay. When a jet fighter came whistling down an ice-covered runway, or one which had been hoar-frosted, one could see stuff being thrown up on its low belly and freezing on it. To deal with such conditions it was ruggedness which was wanted rather than fine engineering, in his opinion.

Mr. B. S. Shenstone, on the question of value per pound weight, said he would be very glad to give some figures in writing; he had not them available at the moment. They were different for each type and for the sort of operation, the number of flying hours per year and so on. Every time a modification was put forward in B.E.A. to one of their machines, they calculated, if it would add weight to the aircraft, what that would cost them over the life of the aircraft due to reduction in pay load, and if that figure was very high it often meant that the modification was not done.

He was glad that Mr. Mills agreed with him on the general question of tolerances. It was certainly sometimes cheaper to make the tolerances closer to get higher performance out of a piece of equipment, instead of redesigning the equipment for the higher performance, but in the long run it might be better to redesign the equipment. Mr. Mills' point had been that they could not afford to buy the new equipment but could afford to buy similar equipment to that which they had been having, but with finer tolerances. He had been very pleased to hear Mr. Mills say that the customer was always right; it was something which B.E.A. did not hear very often.

Professor E. J. Richards (*Head of the Department of Aeronautical Engineering, University of Southampton*) took up Professor Connolly's point about why it took so long to produce an aeroplane, and suggested that there should be included the time from the moment when it became possible to think in terms of a certain type of aeroplane until the time when it was in service.

It seemed, he said, that the reason why the Americans could get through this period much more quickly was that they could afford, with the man-power which they had available, a far bigger wastage rate. They could build two aeroplanes and accept only one, and they did more than that. One of the essential differences was that in this country, with its existing manpower, it was necessary to think much more carefully about how to employ it and produce the same results. It seemed, therefore, that Britain would always have difficulty in being as rapid as larger countries unless the risk was taken of producing the wrong aeroplane. If it were accepted that there must be a wastage rate in order to have an efficient aeroplane, it would be well worth while discussing whether or not the wastage rate in this country was the right one with the existing manpower. It would be very interesting to hear what type of wastage rate occurred with the spares produced for the R.A.F. Were there many of them which were not used, and would not it be more sensible to have increased that wastage rate, particularly on things which were unlikely to be used, in order that they might be produced when the production line was in being, and not asked for afterwards, which was quite a hopeless thing to do?

Following on from that, he would suggest also that the wastage rate was not really assessed properly, even before the aeroplane got into the makers' hands to produce. He felt that the Ministry nowadays took far too long to think about what aeroplane was feasible. The reason for their doing so was that there was much at stake in ensuring that the right aeroplane was produced; it seemed probable that a great deal of time was wasted, and instead of saying "Let us get on with it and build an aeroplane, even though it may not be quite the right one, and save a whole year by doing so," there were committees and working parties studying the matter, and eventually an aeroplane was made which was not very different from the one conceived in the earlier stages. That seemed to be one of the ways in which time could be saved. It meant a risk, and the possibility that what was not the right aeroplane might be produced, but looking round the industry from the outside there seemed to be a great deal of frustration and wasted time, and he felt sure that more aeroplanes could be produced if a more "hell for leather" attitude existed.

Coming to the design side, wastage again came into it. It had always struck him that most of the troubles which slowed up early production arose from certain parts of the aeroplane—tailplanes, controls, undercarriages and so on. He felt that here again a policy of duplication, making two completely different sets of tail units, for example, might well save three months, although it might be that the second tail would not be used at all.

He wondered whether that was feasible. It was an approach to cutting down the period of seven years, which was a fantastic time. If that attitude were adopted, he was sure that the country would have more aeroplanes in a shorter time. There might be more which were not quite the right aeroplanes, but he felt that they were getting a little too introspective, and that their whole attitude of mind was "We have not much man-power, therefore let us be very careful what we do with it". As a result, they did not really use the man-power as well as they should.

Those of them who were in the Southampton area were very well aware that their keenness to build aeroplanes had tended to be stifled because it did not fit in, and instead of saying "Let us have a real go and see what it is like", they had had to wait. The total cost to the country depended on the man-power and not on anything else, and if people could be encouraged to work twice as hard there was no real wastage, but only an apparent one.

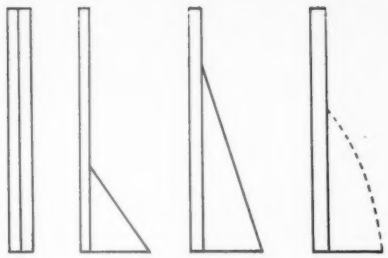
Air Marshal Sir Owen Jones, commenting on what Professor Richards had said, agreed most definitely with the view that the Americans put a wide man-power effort on to something new in a way which was not done in this country. The inevitable result, as he saw it, was that the Americans got an answer, and probably that accounted for the advantage of a year which they were said to have over this country. There could be no denying the fact, however, that part of the development man-power which the Americans used might be wasted. In this country the practice was to look at the problem in a different way, to think very hard for about a year about what they were going to do and then use all the available man-power to do it. He felt that if we followed the American method and put the available man-power on to the whole field, wasting some of it, the time taken to produce the aircraft would be still longer. He did not know whether there would be general agreement on that.

The point which had been raised about spares wastage was an extremely interesting one. The present method of looking at the problem might be represented by taking a column, *A*, representing the whole of an aircraft and considering it as broken down into spares. There was a spares requirement which could be represented by the shaded triangle *B*, whose horizontal dimensions indicated quantity. There were certain things in that area which they knew they would want in quantity, and they tried to make their calculations accordingly. As they went up the scale, they required fewer and fewer of any particular item. This was all done by estimating at the time of ordering or at the design stage. Towards the top of the column there was a whole range of things which they almost certainly would not not want. They knew definitely that they would never want those that came at the very top.

He had his staff working on an exercise now which dealt with this matter. If they had 200 aeroplanes on order, and ordered 10 aeroplanes-worth complete of spares, in other words, on the analogy of the column, having (a) instead of (b), what would it cost them? The second question was what it would cost them if instead of having 10 aeroplanes complete as bits delivered off the line, they had something which could be represented by (c), or again what it would cost them to have something as represented by the dotted line (d). What would be the insurance premium against spares shortage they would be paying in the different cases?

He did not know whether that set of exercises would yield any result, or whether it would mean that they would have on the shelves, at the end of an aircraft's life, a whole lot of unused stuff which had cost an enormous amount. It was a question of whether they would have too much or of whether the insurance rate had been worth while.

Mr. B. S. Shenstone, also dealing with what Professor Richards had said, remarked that he could confirm certain



aspects of the American attitude towards the solution of the problem. He had been told by an American Colonel in charge of a certain kind of development: "There are two ways of doing things. Any fool can write out a list of perhaps twenty solutions to a problem. You can then sit down and think about the problem and be able to throw out eighteen of them and try two, or you can try the whole twenty. I have no time to think, and I have the men, so I try them all."

In B.E.A. they spent a great deal of time thinking about new types and variants, and he found that the longer they thought about them the more ideas they had and the more their ideas changed. As far as he could see, there was no particular optimum time, because no matter how long one thought, one would never come to a final conclusion. Not only was one developing ideas of one's own, but outside influences were having their effect, so that it was never possible to come to a proper solution and at some time or other it was necessary to say: "This is as far as I can afford to go, but I know that it will not be quite right, because ideas change". What was the optimum time to take? Should it be as short a time as possible or as long a time as could be borne? He would be glad to hear comments on that.

Mr. L. W. Rosenthal (*Co-ordinating Engineer, Saunders-Roe Limited*), dealing with the problem of producing aeroplanes quickly, said that his own experience had been fairly short, but there were a few ideas which occurred to anyone concerned with design, and which must also be obvious in the works. If one had an abundant staff waiting when starting an aeroplane, a very rapid build-up of men could be arranged, thereby flooding the job with labour and turning out the total number of drawings in a fairly short time. Work would then run right down to nothing, and the staff would be virtually unemployed. That would be completely uneconomic and with the labour situation as it exists today, would be completely impossible. If one had a number of jobs running through the organisation with peaks in the right places at the right time, redundancy would not arise and one could afford to carry a much bigger staff to cope with the work than is possible with the industry as it is today. Possibly that was a reason why the Americans could flood a particular job with a vast number of men. Doing it that way appeared to cost more, because it meant starting in the office on some items before knowing all the parameters which influenced their design.

The time taken to design an aeroplane and produce the first prototype was roughly three years for a single-seater fighter and four years for a twin-engined fighter. That was to get the first aeroplane. There then had to be flight trials and the time occupied with these was getting greater and greater. People spoke hopefully of one year, but it was more often two calendar years of prototype flying. Production did not appear to go ahead until the best part of that flying had been done. Steps had been taken in the last few years to increase the number of prototypes in order to cut down what might be called the "dead" period. It would be interesting to hear what others had to say on how the whole problem should be approached, because it was one which affected everybody.

Mr. Shenstone's scathing remarks on certain aspects of the British aircraft industry did not tie up with the advertisements in the technical press about the excellence of the products.

Mr. Rosenthal said that the figures quoted by Mr. Shenstone for utilisation rates were very interesting. For his Vikings the utilisation rate was about 1,500 hours a year, whilst the figure for Dakotas of 40,000 hours in fifteen years have nearly 3,000 hours a year. One would expect that with a great number of DC.3 type aircraft the utilisation rate would be higher, but it would be interesting to have some indication of why the rate for British aircraft was less than 2,000 hours. To what extent was that affected by bad design or bad workmanship? Were those in fact the material factors?

Mr. B. S. Shenstone replied that there was a great deal which could be said on the question of relative utilisation, had there been time. Essentially, the European picture was such that it was not possible to utilise aircraft in the same way as could be done in America, mainly for two reasons. First, due to the rather bad hotel arrangements on the Continent, people did not like leaving England late in the day to arrive at Zurich or Vienna at some unearthly hour, because they knew that they would not get an hotel or find any transport, and they would be in a strange place with a strange language. They therefore preferred to travel by day. There were a good many aerodromes which were not open all night long, and a number of the airports were of very low standard compared with any airport from which B.E.A. operated in this country; in quite a number of places there was only one runway. That limited the hours in which it was possible to operate the aircraft. In America it was possible to take an aircraft and fly right across that continent, taking a DC-3, for example, and stopping every 300 or 400 miles to set down and pick up passengers.

The B.E.A. could not do that, and that was the second reason for the difference. They could not fly from London to Paris, Paris to Nice, Nice to Vienna, Vienna to Amsterdam and so back to London, because they could not pick up passengers between those places, that being the prerogative of the national air line involved. The B.E.A. could take passengers from London to Paris and from Paris to London, but not from Paris to Nice. In other words, their operation was star-shaped; they radiated from London and back to London, and only in a few special cases were they allowed to pick up people *en route* and take them to another stop. One of the routes where that was possible took in Rome, where they were allowed to take passengers from Rome to Athens, largely due to the fact that the Italians had not yet made a great effort to build up their air lines. Once this country had sold a large number of aircraft to the Italians, B.E.A. might not be allowed to pick up passengers in that way.

During the war there had been an acute shortage of aircraft in the U.S.A. for their air lines, as there had been everywhere else, and very large numbers of people wanted to travel, mostly not at their own expense, so that the aircraft were always full, all day and all night, for some years. No matter when an aircraft left an airport, there were always people willing to travel on it, and no matter at what hour it arrived people would travel by it. This trend had continued since the War. There were no language difficulties and no passport difficulties in that vast country, so that the aeroplanes could just pile up the hours. The Viscount which was now going into service could easily pile up many more hours if the conditions surrounding its operation were more favourable to it.

Mr. F. R. Elliott (*Design Section Leader, Sir W. G. Armstrong Whitworth Aircraft Ltd.*) endorsed some of Professor Richards' remarks about the time taken to produce an aeroplane, and said that designers were constantly set the problem of trying to design a successful fighter on the drawing-board, although he thought that it would be far more economical in time if they were allowed to design a flying shell first and then try to make that into a successful fighter. Invariably they were asked to fit equipment which was not yet complete into the design, although it might fundamentally affect the shape of the aeroplane. Moreover, the aerodynamic problems involved were sometimes so severe that it was almost impossible to solve them at once, whereas if a flying shell could be made quickly and flown the aerodynamic problems could be solved while the equipment was being developed for the aeroplane.

These remarks applied particularly to the control problems of a supersonic fighter, many of which were still unsolved.

Mr. A. E. Woodward-Nutt (*Principal Director, Research and Development (Aircraft) Ministry of Supply*) said he wished to comment on two points made in the discussion. Reference had been made to prototype aircraft requiring one, or even two, years of development flying. Today, before a military aircraft could be released for service, about twelve aircraft years development flying were needed. Mention had also been made of the cost of aircraft in terms of pounds sterling per lb. all-up weight. This could be misleading. Some aeroplanes today carried more than 50 per cent. of their weight in fuel, and a better figure was therefore cost per lb. basic operational weight or structure weight.

So far as the design of military aircraft was concerned, he disagreed strongly with the last speaker, because the one thing which they must not do in future was to design an aircraft first and then see where they could put in the equipment. It was essential to integrate the aircraft and its equipment from the outset, and more and more essential to design the two as an entity.

The question of how quickly it was possible to get aircraft was one which interested the Ministry of Supply very much indeed, and an important point was when a production order should be placed for an aircraft. The production engineer said that it should be done "off the board", but what did that mean? An aircraft was sometimes on the board for three, four or even five years; at what stage should the order be placed? If it was placed at the beginning, it was inevitable that changes would arise. Assuming that both the production and the design engineers had the one object of producing the *best* aircraft quickly, and not just *an* aircraft quickly, it was inevitable that in the period between the original design and the aircraft flying there would be a large number of changes. Design was not an exact science, and no designer could design an aircraft right the first time; he had often to find out the snags by flight experience. Further, in the four, five or even ten years of development there was ample time for requirements to change; they *must* change, for the reasons Sir Owen Jones had shown. Any process which was adopted, therefore, must be flexible, and there was presumably an optimum time, which probably varied with the type of aircraft, to place an order.

In America things were done in rather a different way, and he would like to hear views on whether it was a better way. He was not sure that he accepted the suggestion that the Americans were one year quicker in evolving aircraft than we were; he thought that that was open to question. What the Americans normally did with military aircraft was to order a design and a working mock-up in the first place from each of a number of manufacturers. At a later stage they picked out one or two types and ordered a relatively large number, twenty or more, development aircraft, which had to be built on some kind of production jigs and tools. Those aircraft were used for a wide variety of development tests, but they were produced at a slow rate and differed as they came off the line, as improvements came in, until the final one in the batch, or sometimes the one before the final one, might be fully representative of the ultimate large production order. Should that be done in this country? Should a large production order be placed straight away, or a limited order on the American pattern, or, as was done here now, an order for one or two prototypes followed some time later by a production order? He would like to hear the views of production engineers on that.

The Chairman regretted very much that the time allotted to the meeting had expired. In concluding it, he proposed a cordial vote of thanks to the two principal speakers, which was carried by acclamation.

CONFERENCE SUMMING-UP

by SIR FREDERICK HANDLEY PAGE, C.B.E., Hon.F.R.Ae.S., Hon.F.I.Ae.S., F.C.G.I., Hon.M.Inst.T.

Chairman: Walter Puckey, M.I.Prod.E., F.I.I.A., President of the Institution.

Sir Frederick Handley Page

MY task is to sum up. Now that tense moment has come when the murderer in the dock is waiting to hear whether the judge is going to sum up favourably or unfavourably, and whether his life will be extended or come to a sharp and short end. We have heard the case for the prosecution and the case for the defence. I am not quite clear which is which. We have heard Mr. Shenstone say that the operator gets all the blame, with the manufacturer slinking away in the background, though it was inferred, but not, I think, explicitly stated, that the manufacturer ought really to have been in the dock.

But, after all, this is only the summing up, and there is a jury which will give the verdict. The jury, for civil aircraft, is public opinion, expressing itself by the support which is given to civil air transport by fewer or more passengers travelling. There we have to face some facts which are not very palatable. In particular, I do not think that it is good for civil air transport when a famous musician such as Yehudi Menuhin says that he will no longer travel by air because of various friends lost in aircraft accidents. Therefore, while we are all rightly concerned, and particularly concerned in this Institution, with the problem of production, we have to work in every way we can in the fullest co-operation with those who are directing air services, to ensure that everything is done to make aircraft safe.

Time and Production

Throughout this meeting there has been a good deal of emphasis on the time scale for the production of prototypes and on the time taken to put those prototypes into production. I must say that I have learnt with amazement that other countries do it better and more quickly than we do. I think that as a judge, and therefore going only on facts and not on the emotional impulses of the moment, I would say that the statement about a quicker time abroad, without specifying any particular country, is inaccurate. A recent survey has been made of the time from the inception of the design in this country to the time when the aircraft has got into squadrons. That survey has covered fighters as well as heavy bombers, and I think it is true to say that there is very little difference in time between the time taken in this country and elsewhere; if anything it is in favour of this country.

We have to think of the great change which has taken place in regard to the position of this country's civil aircraft manufacturing and operating activities as compared with the position just at the end of the World War. In the war effort the designers, the manufacturers, and the Air Force all worked closely together as a great team for the common object of victory. Our concentration was, however, on military machines, whereas the development of transport aircraft proceeded apace in the U.S.A. The value of that war effort must be judged by the fact, which we sometimes forget, that after all we did win the War, and that War we won by being superior in the air—the best tribute that can be paid to the work which was done. Since that time, our position in the world of air transport has changed and now I think that everyone must admit that we are a good way ahead of our friends in the United States, and that we have achieved this position in spite of the way in which—according to some critics—we are supposed to lag behind.

When we come to survey the aircraft field, we have to remember that we are dealing with an industry which has to cope with a rapidly-changing technique, a technique which is changing much more rapidly than that of any other kind of industry in the world. All the time we are producing things against an ever-increasing set of requirements, not because of change of specification but because the enlarging of our field of experience is going on all the time, and we want to incorporate in the latest aircraft all the results of that experience. It is inevitable, therefore, that the incorporation must lag behind the accumulation of that knowledge.

Placing the Order

It is very important to remember that if you want to get aeroplanes, whether for civil or for military service, the first thing to do is to order them. That is usually the most difficult thing to get the customer to do; he may be always right, but he is so much to your right that you do not get a chance of getting him to come along and sign on the dotted line. When people are assessing things backwards and forwards in this way, the great point is to come to a decision and make a start on doing something. Apart from the technical requirements, there is a good deal of fashion in what goes on in aircraft. I believe that the aircraft designer and the technical developer have to deal with something which is almost like the vagaries of women's fashions, but with this difference, that women's fashions usually go in the direction of producing a product which looks as though it was falling of at every moment of its use, whereas the aircraft designer has to produce something which looks as though it was going to stick together. I believe that we must make decisions very much earlier and more quickly, because all the time we have to remember that there is this incessant demand for the incorporation of new experience, and the longer we wait the more modifications we are likely to be asked to incorporate.

Figures have been given of the time which certain aircraft take. I think that Mr. Woodward-Nutt mentioned 12 years, and someone else referred to one year for the Mosquito. If you want to have figures for the quick production of aircraft, you have to go back to the First World War. My own company started on the big four-engined machine which was going to bomb Berlin at the beginning of October, 1917; it was flying in April, 1918, and ready in a squadron for flight in October, 1918. Why was that possible ? Simply because there were not then the requirements which exist today. As an illustration, I can tell you that the total man-weeks in the drawing office from the inception of that machine—and a pencil was not put to paper nor a calculation made prior to October, 1917—were 600. You cannot put your nose inside an aircraft drawing office today and talk to the people there without finding that about 1,000 man-weeks have gone in discussing whether you are going to make it, whether the customer really knows what he wants, and, if he does want it, whether it is possible for you to do it.

With the Halifax bomber in the last War we started on the design in August, 1937, and 120 working weeks afterwards, in October, 1939, the first machine was flying. Production started in 1940, building up to quite substantial proportions in 1941. The Halifaxes were going into the squadrons in 1941 so that from design to service use was only four years. You can add the time before 1937 when people were considering the specification and doing some thinking about the job, but I am not sure whether that time should be added.

I am, indeed, sorry that I was not able to be here yesterday to listen to the three Papers which were then presented. It is interesting, in this fiftieth anniversary of flying, to remember that the Wright Brothers made a note in regard to designing for production. One of their earliest patent specifications read as follows: "The objects of our invention are, first, to provide a structure combining lightness, strength, convenience of construction and the least possible edge resistance". In other words, they were going to have convenience of construction and to design for it.

At the present time our problems, which have been dealt with so fully at this Conference, tend to centre round the developments which are going to come because of high subsonic flight or supersonic flight. Mr. Keith-Lucas, in the first Paper gave an admirable address—very well delivered, so I am informed—on some of the problems with which we have to deal. In the discussion the speakers were concerned with different views on pods, thick wings, thin wings and so on. We have to remember that our American friends have a different problem from ourselves. They have a problem which involves longer distances and therefore big range and big fuel capacity, and they go in for thin wings and big spans. Without big spans it is not possible to get real efficiency over long range, and, having thin wings, they have no room to place the engines or undercarriage in the wings, and therefore they have gone to pods underneath the wings and to the undercarriage under the fuselage. Once you start on that line of development, there is a whole host of other things that follow. Eventually the type of aircraft developed is quite different from that in this country.

Integral Construction

An interesting point in Mr. Keith-Lucas's Paper and in Mr. Woodley's Paper is that of integral construction, where the skins are milled out, and reference was also made to the use of heavy presses. One thing which we must always keep in mind is the need for the rapid expansion of production in time of war. One of the problems which faced this country in 1939 was that a great many of the designs were based on the use of extrusions, even down to small extrusions. When the position was surveyed to see the possibilities of rapid expansion, it was found that there were only one or two extrusion presses in the country, and a great deal of emphasis had to be placed on getting more extrusion presses brought into this country or manufactured here. If the expansion of the aircraft industry in time of emergency depends on the use of a great deal of capital equipment, and particularly capital equipment which necessitates a great deal of tooling, then inevitably there is going to be some delay before the expansion takes place. We must not overlook the prime importance of the time taken to expand production should an emergency arise, as distinct from getting into production.

Mr. Keith-Lucas referred to different shapes of wing—some straight, some swept-back, some delta, and some, and the best of all, crescent—but I do not think that from the production engineer's point of view it really matters very much which are used. What does matter is that, whatever is designed, the

production people have been in it right from the beginning. It is no use, I think, starting on a job in which a wonderful machine is designed, and some great Leonardo da Vinci, an aeronautical expert, says "Now productionise it". You cannot do that; the production staff have to be in from the beginning.

Importance of Equipment

I thoroughly agree with Mr. Woodward-Nutt that you cannot make a shell and fly it and then put the equipment in. I think that perhaps the aircraft is the chicken and the equipment is the egg. Which comes first, the chicken or the egg, will always be a debatable point, but today equipment is playing a more and more substantial part in the use of aircraft, and the airframe is becoming less and less the important cost in a new aeroplane, so that we must, whether we like it or not, start with a big enough aeroplane and the equipment properly put into it from the very beginning.

One of the great advantages of the Mosquito, which was referred to earlier, and which only took twelve months to get into production, was that the fuselage was so small, relatively, that it was not possible to get any more equipment in it. So one could take all the different departments of the Ministry of Aircraft Production down to see it and say "There it is, gentlemen; you can put anything you like in it, but it must all be inside the fuselage". One speaker referred to making the shell first. If the aircraft fuselage is too small to contain the essential equipment, it is no use having the aeroplane. Like all these problems, there is no easy answer. None of the problems of this world is black or white; they are always grey, and we have to compromise between different things which we consider desirable.

The other person who must be in right from the beginning of a design is the service engineer, who must bring back into the design office the experience of operation in the Service or in civilian work. Hydraulics and electrics require a great deal of attention, and we must have the Service people in at an early stage. Nowadays we start with a number of black boxes like coffins which we are supposed to put in. We do not know what they are for, and probably by the time the aircraft is made we find that they have doubled in size. Having carefully streamlined the nose, we have a demand for a flat plate at right-angles to the direction of flight and about 5 feet by 6 feet—all of which helps us to fly at a higher Mach Number!

Use of Fine Tolerances

Passing to the Papers by Mr. Dowty and Mr. Woodley, I was a little scared, I must admit, when Mr. Dowty talked about tolerances of 0.0002". A point, which I think several speakers have made in the discussion, is that if you are getting these very exact limits you will be faced with trouble at some time or other because, particularly with civil aircraft, where the machines have to be used for a large number of hours, wear and tear are bound to cause trouble later on.

The use of titanium has been referred to, and there I think that some more active steps have to be taken either by industry or by Government organisations, or by a combination of the two, to ensure that more titanium will be produced in this country than is budgeted for at the moment. According to figures which I have seen, the production of titanium in this country will not amount to much for three or four years, and at the end of that time it will be only about one-fifth of what one can envisage as being capable of being used over here.

Mr. Woodley referred to large forging presses and to big machining requirements for certain types of design. I would again emphasise the point to which I have already referred, namely that if there is this big capital equipment which has to be expanded in time of war, it is liable to create difficult bottlenecks. We have to consider how we can turn from the 10, 20 or 50 aircraft which we make in peacetime to perhaps a thousand aircraft which I think someone mentioned.

Training Production Engineers

I was very interested to read in Mr. Dowty's Paper about thick anodising providing harder surfaces than chromium plating. I was also interested in his remark that 30% of his company's apprentices were now passing out in production engineering as their main subject. There is a difficulty which confronts us here. When we have engineering apprentices who are capable of theoretical work of the highest order in aerodynamics or in stressing, it is easy for those lads to judge their capacity; they can test themselves by the place which they gain in an examination. When they come out of college or apprenticeship, taking an apprenticeship after college, or, apprenticeship and part-time study, they know pretty well where they stand technically. They do not know, however, exactly where they stand from a personality point of view.

When these young men come out of their apprenticeships, it is difficult for them to decide if they should go into the works to gain supervisory experience—perhaps as a leading hand or charge-hand—and whether they are likely to stick half-way up the ladder in the works instead of becoming a works manager or managing director. They tend, therefore, to find their way through the wide-open doors of the technical departments of firms, and they move down an ever-narrowing corridor and end in a technical pigeon-hole without any windows and wonder why they are not on the board of the company and dealing with a broad survey of world affairs in relation to their company. That is because these lads are diffident about going out on to this sea of human experience and learning to manage and control men.

For that reason all engineers, and production engineers in particular, must serve their time in a shop on real engineering, getting into the very marrow of their bones the atmosphere of the shop, which cannot be learnt anywhere except in a works. With great respect to those who teach post-graduate subjects, if you want to become an engineer the best

university is the university of life in a works, knocking up against other people, finding out their ways, being told by the men about their domestic difficulties, realising that the men in the shops have a life to lead, like you, and have the same enjoyments, though they may be limited to football pools and perhaps backing Southampton. It is with these human tools that you will have to work. I was very interested in what Mr. Dowty had to say about that.

The Modification Problem

The real trouble to which Mr. Woodley referred in his Paper is the continual change which goes on and which leads to modifications. I believe it was Lord Northcliffe who said "Never make an experiment on an experiment," but both words are in the singular. In aircraft we are making experiments on experiments all the time, and many of the experiments are being carried out on equipment which is not under our control. Whilst we can find ways of adapting our aircraft to the various changes in the equipment which are made, we have a very difficult job because of these changes with which we have to deal.

I was very interested indeed in Mr. Woodley's remarks about copy machining and so on. I think we have to remember that in this country we have not an unlimited number of good people in any walk of life, any more than they have in the U.S.A. It is an outstanding fact that while between 1912 and 1952 the number of people entering a university—if that is any guide to capacity—increased fourfold, the number taking first-class degrees did not increase materially. We have to remember all the time that this wide range of human personalities with which we are dealing, these organic machine tools without which no works can be alive, are very much like an ordinary herbaceous border in a garden: there are tall hollyhocks and sunflowers and tiny forget-me-nots. However hard you try you will never make a forget-me-not into a sunflower, and it is the same with the variegated people with whom we have to deal. It is only the very skilled people at the top in all walks of life who are available to do the higher grade of work, and as production engineers we have to think very hard about how we can utilise the good quality materials without making too great a drain on the human resources of this country.

We have still to face a great many problems, and the problem of bringing in titanium is one which is going to tax people to the utmost, particularly in regard to its use around the engine structures and so forth, or in the engine units, where the ability to withstand heat is of prime importance.

The Operator's Opinion

I listened to Mr. Shenstone's Paper with very great interest indeed. I think it would be a very good thing if the operator would come in and design and make the aircraft. How marvellous they would be! Some of the points which he made caused me to think, what perhaps I have sometimes wrongly thought, namely how badly B.E.A. purchase their aircraft!

He spoke about various points which are bad. It is very easy with any aeroplane to find faults, but very often the operator concentrates on these and forgets the good points. I have often found that when you go from one type to another, the things which caused the troubles in the previous type are looked at most carefully and the things which are good are very often forgotten, so that when you come to the next type you have got over the bad points of the previous type and not kept the good ones.

With regard to interchangeability, I think that every manufacturer who wants to make anything with the human machinery at his disposal has to make things properly interchangeable, not from the point of view of the operator, who is very much in the background at that stage, but for ease of manufacture. I do not think that anyone worries about the distance between the wings and the tail, from the point of view of interchangeability in the field, but many of these overall dimensions are important for manufacture although they may be of no interest to the operator. You must, if making the fuselage in a jig, have the pick-up points right, so that the parts going into the jigs will always fit together. Pick-up points on the wings or on the tail are of prime importance from the operator's point of view, but they are of no more importance to the manufacturer than these other big dimensions. We have to make things so that they readily go together, and by and large I think that this country turns out parts which are interchangeable to a very high degree.

There are times when, with something which is three thousand miles away, distance lends enchantment to the view. You do not hear of all the things that happened in development, but when you have one of Mr. Shenstone's engineers sitting with you all the time, he hears about all the difficulties, and what a tale of woe! I do not think that that is necessarily right.

Jig Design and Manufacture

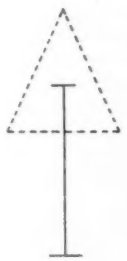
One point on the subject of jigging is that the manufacture of assembly jigs is quite different from, and should be viewed differently from, the manufacture of an aeroplane. With an aeroplane you have to make wings, fuselages and everything else over and over again, and therefore you want great interchangeability of everything in them. When you make a jig, the only dimensions that must be exact are those of the pick-up points. There is no need to make any drawings to make an assembly jig, if you have competent ironfighters. You give them a drawing of the main plane and say you want a jig for it, and so do away with a good deal of work in the drawing office. It has been said that a drawing office exists to make drawings of something which the works cannot make, and it is much better that the people who have to use the jigs should make them, simply ensuring that the pick-up points are right.

In all these things what is most important is to

have a good team working together on the whole job. The designer is no good unless he has good aerodynamics and stress people and a good test-house and a good wind tunnel, and the production engineer must have good jig and tool people, and they all have to have their say right at the beginning. Every design should start with the exploded drawing and should be broken down to see whether people like it or not.

Provision of Spares

I was very interested in what Air Marshal Sir Owen Jones had to say with regard to spares. As I understood his sketch, the column represents the life of the aircraft from the time of its inception to the time that it goes out of service, and he showed how the spares are ordered so that they are on a broad base. I am under the impression that the spares, ordered usually some time after the aircraft for which they are designed, could be represented by the dotted lines in relation to the production time scale of the aircraft. I suggest, and I think that those of you who have a knowledge of the forces which gravity exerts will agree, that such a structure is top-heavy.



On the question of spares, their ordering and production would be simpler if they were divided into categories. Category 1 would consist of all those parts which move relative to one another — the controls, the moving parts in the engine nacelle, the undercarriage and so on. All those parts which move relative to one another must suffer the greatest wear and require the greatest number of spare parts. You assess those at, say, 15% of the amount in the aircraft itself. Then you come to the other components, such as the wings. The wing-tips, rudders and elevators, which are liable to damage, come in the second category. All those things should be ordered at the same time as the aircraft. It is a great mistake to consider the spares only at a much later date.

On the question of ordering more or less, under the present scheme far too much money is being lost in the later stages of the production and operation of aircraft by reason of the hold-ups of spares. At about 12.30 on a Saturday morning there comes a most important and urgent A.O.G. for something the need for which has just arisen and which is wanted at once. With the best will in the world, the number of rabbits which the aircraft constructor can get out of his hat is very limited, and very often what is wanted is something of a special type which will take a long time to produce. It is worth considering whether we cannot tie these things together better.

The same remark applies to the small order shop to which Sir Owen Jones referred. It is all very well to set that up separately, but when there are not orders for spares and the shop is there with its jigs set up, on what are you going to employ it? There is jobbing work, making odd spares from time to time, the need for which arises because of an accident which nobody foresaw. You have to be able to deal with things of the kind which a garage does for motor cars; if the garage cannot get the spare part which is needed from the manufacturer, it may have to use something temporary in its place. That is quite distinct from the main manufacture.

The best plan would be for the manufacturers to carry spares in a binder store. It would then be possible to use them in the main production, keeping the stock replenished and having a flow in and out of the stores. As experience grew and it was found that certain spares were not being required, they could be absorbed into the main production.

I have only cursorily gone over these points. If I may sum up, I think that one thing that we have to do from the design point of view is to make things very much more simple and with a smaller number of parts. There is too much chasing after the thinnest possible gauges and then reinforcing them with stringers and so on. Whether those stringers are reduxed on or spot welded on or riveted, it maybe does not matter. We want a smaller number of parts all the way through. When that is attained the production engineer's job is very much simplified.

Finally, I should like once more to remind you that the eventual verdict will be given by public opinion and not by anything that we settle ourselves.

BRITISH STANDARDS

The following Standards have recently been issued and may be obtained post free at the prices stated, from the British Standards Institution, British Standards House, 2, Park Street, London, W.1 :—

B.S. 2054 : 1953. Augers and Auger bits (4/-).

B.S. 2061 : 1953. Phosphor bronze spring washers for general engineering purposes (2/6d.).

B.S. 1580 : 1953. Unified screw threads (with metric equivalents) (12/6d.).

FACTORY EQUIPMENT EXHIBITION

The second National Factory Equipment Exhibition will take place at the Horticultural Halls, Vincent Square and Greycoat Street, Westminster, London, from 22nd/26th March, 1954.

The Exhibition will be opened by Lord Rochdale, the newly-elected President of the National Union of Manufacturers, and a well-known industrialist.

CORRIGENDUM

Attention is drawn to page 588 of the January Journal, where reference is made to Mr. W. G. Key as Chairman of the Wolverhampton Graduate Section. Mr. Key is, of course, Chairman of the Coventry Graduate Section.

COMMUNICATIONS

The following comments on the Southampton Conference have been received.

AFTER THE CONFERENCE—WHAT ?

From: Mr. Walter Puckey, Kt.,

President of the Institution.

Professor Connolly of the Department of Aircraft Economics and Production at the College of Aeronautics, Cranfield, said during the recent Conference that those present had largely failed (so far) in getting down to fundamentals. How true was this statement? Did the Conference really achieve all that the Southern Section of the Institution had hoped?

My view is, that in common with most Conferences, it presented too great a variety of food, and in doing so produced an unbalanced "meal", and a strain on the mental digestive organs.

The aircraft industry is of great importance to the nation. In war, it is and will be our greatest striking force; in peace, it has gained in virtually a few years an outstanding position as a supplier of the world's fastest means of travel, and has become an industry of even greater financial value than traditional shipbuilding.*

By any standard, it is an industry of great importance and it is right that we should examine critically its problems and in particular, its growing pains, so that the greatest help is given in helping it to reach even greater maturity.

Rarely, if ever, has an industry progressed so far so quickly and the recent Jubilee celebrations at Kitty Hawk have shown that packed into fifty years has been a variety of experiences, designs and triumphs unequalled in world history. The industry has shown almost violent technological progress within the lifetimes of many of us and, as in the past, so today and tomorrow; the Comets, Viscounts, Javelins and Vulcans are many technological years ahead of their immediate predecessors and the future holds many developments in store. And if this is not enough, we find this great industry carrying too the major burden of "guided weapons" development and production.

It would take pages to describe the problems of the aircraft industry, although many of them are closely allied to the engineering industry and to the readers of this Journal. Indeed, one particular problem of the aircraft industry is the great spread of activity into and reliance upon many other industries, with all the difficulties of sub-contracting, design integration, quality and timing involved.

*Statistics for 1953.

This problem was exemplified by the attendance at the recent Southampton Conference, and a large percentage of those present came from firms outside the "airframe" industry, i.e. those firms producing complete aircraft or large sections such as wings, and this is not surprising, as although individual aircraft vary greatly, it is probable that 50 per cent. or more of the man-hours required to produce a complete aircraft are expended in producing its equipment, the electrics, electronics, hydraulics and, in the case of military aircraft, the armaments and other warlike items.

So, therefore, when we talk of problems of aircraft production, we find our scope very wide indeed and we reach the important conclusion that, as there are common problems, there are common solutions to those problems. In solving a problem we benefit not one industry, but many; in tackling a problem of the aircraft industry we can with advantage draw upon our experience elsewhere.

I have already mentioned one of the aircraft industry's greatest problems, the increasing reliance upon other specialists in other industries. I see no sign of this difficulty diminishing; on the contrary, it will increase and its solution will be as much a problem of organisation as of technological progress. The more the specialists, the greater the difficulty of integrating products into a whole, and this difficulty is present in deciding the specification, in designing, in production control, in making, testing and using. I could elaborate considerably on this problem and its possible solution; my only comment here is that it was barely mentioned at Southampton.

Trend of Development

Another real problem confronting the industry is "the shape of things to come". We saw isoclinic wings, deltas and crescents and, unlike one well-known modern aircraft, the ideal solution has not and probably will not land itself. It will remain in the air and the production man will find it more and more necessary to prepare for everything and possibly, with order books fluctuating as they do, getting nothing; or at least getting less quantity production than he would consider desirable to pay for his heavy production investment.

Mr. Woodley's admirable Paper showed us the amount of ingenuity expended to keep up with the designer's demands and, equally important, with the users' delivery dates. Here we have tomorrow's paradox—more complexity and a greater rate of

design change with shorter production orders for any one product on one pan of the scales, while on the other scale are the more competitive needs of the customer to be met, needs that will become sharper in terms of time, quality, price and specification.

There is increasing evidence that designers and production men are working more closely together in attempting to balance these scales and the industry is certainly in good shape to deal with its production problems, being certainly one of the best equipped in the country today. It was, however, noticeable, that no real answer was provided to the heavy press problem, which itself arises from the designer's need for more "integral" construction. I wish I could see a simple answer. It is one thing to refer to the large scale "big squeeze" of America and say that we should emulate it. The British aircraft industry has not itself formulated a clear programme on appropriate British equipment and certain well known members of it are not convinced that such expensive equipment is necessary.

Providing National Facilities

My own view is that we should not hesitate to provide national facilities in advance of the designer's need, particularly in a growing industry such as aircraft. Having said this, however, I still see the need for more agreement on such important problems as the specification of this equipment; how many sets there should be; its strategical difficulty in war; its management; and its availability to various users for development and production. Until these matters are more agreed than I believe they are at present, people will continue to raise the problems without contributing to the solution.

I could refer to other problems but, then every industry has hosts of them and they are surmounted every day. I would like briefly, however, to refer to the problem of quality, raised by Air Marshal Sir Owen Jones and Mr. Shenstone, with in the latter case somewhat ill-balanced publicity in the lay press. Whenever a problem is critically examined there is a risk of adverse publicity, particularly by the lay press whose readers are generally more interested in headline information than in technical statements.

Both Mr. Shenstone and Air Marshal Sir Owen Jones are men of the highest repute and were talking critically, as users, to designers and producers. They had a right to criticise and a careful perusal of the Paper has convinced me that they were constructive too. It is a pity that the constructive sections were not given the same lay publicity as the criticisms. Members of the Institution (and there are many of them) who are suppliers to the aircraft industry, will I know accept reasonable criticism. They will also, in the spirit of progress, concentrate on the many positive suggestions that were made, and will make sure that Southampton played its small part in building a great industry into an even greater one.

I hope that future Conferences will be able to take a great deal further a few of the fundamental problems such as those I mentioned earlier. A grand atmosphere of co-operation has been built up inside the industry which will form an admirable background for greater investigation into the more difficult future problems.

THE MACHINE TOOL PROBLEM

From: Mr. H. A. Chambers, M.I.Prod.E.,

General Manager, Rockwell Machine Tool Co. Ltd.

One of the major points discussed at the Conference dealt with the production of integrally stiffened aircraft skins and the contour milling of intricate panels and supporting members of aircraft. It was emphasised that in order to save weight and achieve more efficient aerodynamic conditions, it was advisable to use much larger pieces and so obviate the bolting and riveting together of small parts. The necessity for designing aircraft in small parts was stated to be due to the absence of sufficiently large plant to deal with bigger pieces.

When examining aircraft works where modern aircraft are being produced, it is seen that the tendency is to build large aircraft with small machine tools, that is, machine tools which were originally installed for small aircraft.

During the Conference methods were discussed which quite obviously were only compromises when compared with what is taking place in the U.S.A. When the problem of the milling of large and intricate parts arose in America, the U.S. Government requested all prominent aircraft manufacturers to instruct their most eminent designers and production engineers of aircraft to decide how it was to be met. The outcome was that the American Government placed a pool order under which individual aircraft manufacturers could acquire aero profile machines to suit their own requirements. Every major aircraft builder in the U.S.A. possesses one or more of these machines, in spite of the fact that the forging press programme is still in its development stages.

These machine tools have been offered to this country by the American machine tool makers with the experience which has been accumulated over the past six or seven years. This offer has not been taken up owing to what is described as the high relative cost.

When one contrasts the cost of a large modern aircraft, say around the half-million mark, against the cost of a modern skin milling machine, say in the region of £80,000 or £90,000, it would not appear to be excessive, especially when the largest aircraft skin of 34 ft. by 4 ft. can be produced in 30 hours. The alternative fabricated skin must take considerably longer and the man-hours are increased accordingly. The paragraph dealing with these

figures in the Paper by Mr. D. Keith Lucas reads as follows:

> "One American firm which does more 'sculptured machining' than most, claims that the cost of production including machining, materials and overheads, is $1.2/3 per lb. against $6 or $7 per lb. by previous methods. These figures are striking whatever the factor of enthusiasm which we may choose to apply."

In view of this statement, can this country afford to be denied the use of the most up-to-date plant enabling the saving of labour and producing a superior design?

This is a matter of great national importance, where a vigorous lead should be given by the Government Department concerned. Following the rapid expansion during the 1951/52 period, some cutting back of the production programme has been experienced. Under present circumstances, therefore, an individual firm may consider it risky to make a substantial capital investment; yet the teething period of integrally manufactured components must be overcome. Instead of acquiring interim plant which some firms are purchasing to overcome immediate production difficulties, none of which is capable of being used on an expanding programme, aircraft companies should be given help as discussed at the recent Conference.

Large sums of money have been spent on buildings by aircraft manufacturers in this country. They also seem to have been backed up by information on design from The Royal Aircraft Establishment, Farnborough. It would, however, seem advisable to consider giving similar support in relation to production methods.

A set of machines on the following lines is obviously essential to the British aircraft industry:—

1. 35,000-ton forging press, complete with heat treatment plant and the necessary die sinking machines, to enable dies to be made to produce forgings which require the minimum machining.
2. A series of automatic profile milling machines with the necessary automatic means to save man-hours and produce an accurate job in dealing with intricate components and integrally stiffened skins.
3. A 20,000 to 25,000-ton extrusion press to produce extrusions to save machining aircraft skins where stiffness is parallel chordwise.
4. Necessary plant to produce billets large enough to give the necessary size sheets and components, together with sheet rolling equipment.

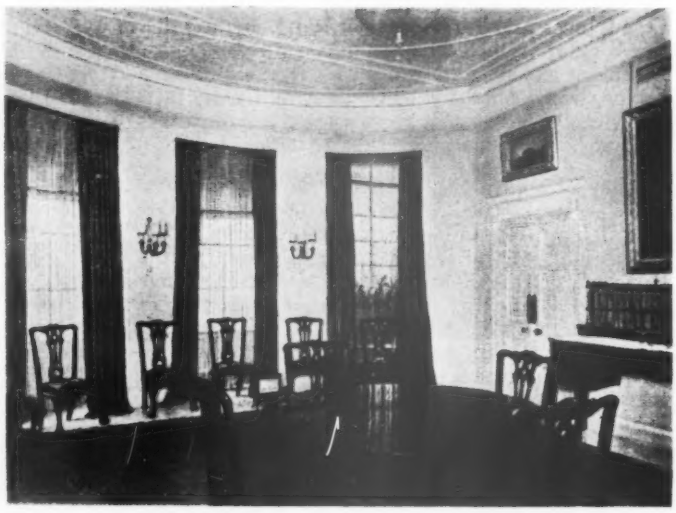
The combined cost of the above plant may reach a figure of, say, between 10 and 12 million pounds but it would, if adopted, enable the aircraft industry to overcome difficulties in the manufacture of important aircraft components and provide the industry with similar advantages to those available to our American friends.

INSTITUTION NOTES

THE NEW HEADQUARTERS

FOR some years past, the Council have had very much in mind the provision of new headquarters for the Institution. When the lease of 36, Portman Square was first purchased by the Institution, provision was made to restore the capital sum by the time the lease terminated. However, the incidence of the recent War completely upset the economics of the Institution's provisions for the future and it has not been possible to fulfil this aim.

The lease of 36, Portman Square will expire in five years' time, and it was strongly felt by Council that the Institution should acquire as soon as possible, permanent headquarters suitable for the foremost association in the country dealing with the technique of production



efficiency. In order to dispose of the present lease while it still had some residual value, no time could be lost in finding alternative accommodation.

The task of finding freehold property suitable not only in appearance, but with accommodation which would permit the efficient administrative working necessitated by the rapid growth and development of the Institution, and at a price considered reasonable, was not easy. It will be clear to members, however, that if Council had waited until the lease had expired before seeking alternative premises, the decision would almost certainly not have been so favourable to the Institution.

After two years' careful exploration, Council have had the good fortune to acquire the freehold of an eminently suitable building, 10, Chesterfield Street, London, W.1, where it is anticipated that the Institution's headquarters will be established in a few months' time.

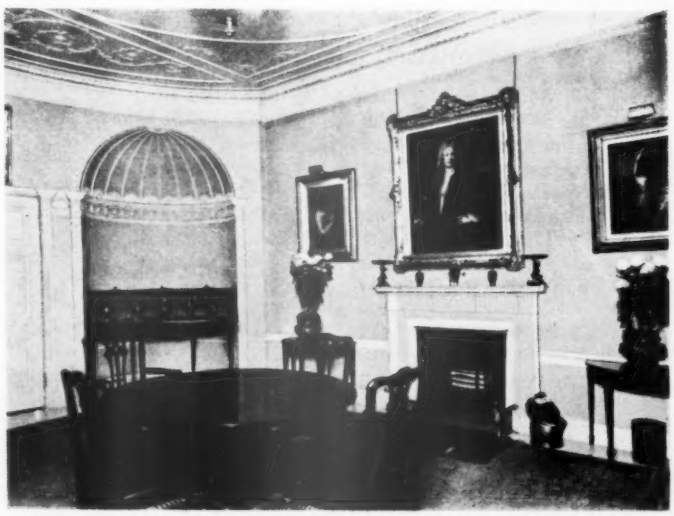
The acquisition of this property is a very important step forward for the Institution, and is a sign of the remarkable progress which it has made since its foundation in 1921.

The house is an 18th century building, solidly constructed and containing several period features, and large enough to provide for expansion in the future. There are 25 rooms compared with 15 rooms at 36, Portman Square, which means that the effective accommodation will be increased by approximately 2,280 square feet, i.e. about 50 per cent. more than at Portman Square.

The accommodation is on basement and four floors and there is a lift from the ground floor to the third floor. In addition to a splendidly proportioned Council Chamber, there are other fine public rooms for the use of members, and a large library, which will be furnished to provide members with facilities for study.

The arrangement of the accommodation is admirably suited to the Institution's purposes and very few structural changes will be necessary. The photographs reproduced here were taken while the house was occupied by Earl Fitzwilliam as his London residence.

The price of the freehold was rather more than had been envisaged, so, in order to avoid the necessity of placing a heavy mortgage on the Institution's annual income, it was decided to invite members to subscribe to a New Building Fund. As the Fund now stands the whole of the Institution's invested capital will have to be used for the purchase and it may even be necessary to raise a small mortgage. This will mean not only the loss of about £1,000 per annum income from investments, but the payment of interest on the loan. It is therefore highly desirable that the Institution should raise as much as possible from the Appeal.



NEW BUILDING FUND APPEAL

Since the publication of the last list, donations have been received from the following subscribers. (This list was compiled for press on 12th January, 1954).

Geo. Bray & Co. Ltd.
H. Burke, M.I.Prod.E.

H. A. Chambers, M.I.Prod.E.
A. R. Chapman, A.I.Prod.E.
P. H. Cooke, A.M.I.Prod.E.
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Members of the Sheffield Section.
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G. W. Stabler, M.I.Prod.E.

J. Tyldesley, A.M.I.Prod.E.

Vauxhall Motors Ltd.

J. Wearmouth, Grad.I.Prod.E.

E. Zagni, A.M.I.Prod.E.

OPENING OF ACCRINGTON TECHNICAL COLLEGE

An event of particular interest to the Preston Section of the Institution took place last December, when the Lancashire County Council's Accrington College of Further Education was opened by Mr. E. G. Eaton, Vice-President of the Section, in the company of the Mayor and Mayoress of Accrington.

In his address Mr. Eaton, who is a Director of Howard and Bullough, Ltd., Accrington, drew attention to the fact that this new College is one of the first in the country to specialise in production engineering, and is approved by the Ministry of Education and the Institution of Production Engineers for training to Higher National Certificate standard in Production Engineering.

Mr. Eaton conveyed to the authorities an official message of goodwill, with good wishes for the future success of the College, from the President of the Institution.

GRADUATE'S SUCCESS

Mr. R. M. Webb, Graduate, has gained a First Class Pass in the City and Guilds of London's Final Examination on "Mechanical Engineers Estimates and Specifications". He also receives the Institute's first prize of a Silver Medal.

In addition to these awards, Mr. Webb already holds the C.G.L.I.'s Intermediate, Final and Full Technological First Class Certificates in Machine Shop Engineering.

B. A. WILLIAMS FOUNDATION AWARD

The Liverpool Section announces that the B. A. Williams Foundation Award has been presented to Mr. A. G. Vine, Graduate, for his Paper, "Methods Employed in the Production of T.V. Aerials". A Merit Award has been made to Mr. G. Smith, Graduate, for his Paper on "Car Tyre Manufacture".

Meeting on "Industrial Finishes"

At a recent meeting of the Norwich Sub-Section, Mr. K. W. Abineri presented his Paper on "Industrial Finishes". With the author (second from right) in this photograph are (left to right) Mr. F. H. S. Heidenstam, Section Hon. Secretary; Mr. V. Crowther, Section Committee member; and Mr. S. Caselton, Assistant Secretary (Administration) of the Institution.

JOURNAL BINDERS

Members are advised that binding cases for the new size Journal are now available, and may be ordered from Head Office. The cases, which are strongly made and covered in dark red leather cloth with "The Institution of Production Engineers Journal" in gilt on the spine, will each hold 12 copies of the Journal. The price per case is 10/-, post free.

A limited number of binding cases for the old size Journal are also available, at the reduced price of 2/6d. per case, post free.

NEWS OF MEMBERS

NEW YEAR HONOURS

The Institution is pleased to record that the following members were honoured by Her Majesty the Queen in the recently published list:

C.B.E. Miss A. G. Shaw, Member, Senior Partner of The Anne Shaw Organisation.

O.B.E. Mr. A. J. Perkins, Member, Superintendent, R.O.F., Cardiff.

M.B.E. Mr. G. H. Rippon, Member, Technical Director, Maun Industries, Ltd., Mansfield. Mr. Rippon is a Past President of the Nottingham Section.

Mr. J. Hastings, Associate Member, Civilian Workshop Officer (Technical Grade I), R.E.M.E. Workshops, Aldershot.

MR. N. C. ROBERTSON

Mr. N. C. Robertson, Member, after two years' voluntary service with the Ministry of Supply as Director-General of Electronics Production, has now resumed his civilian duties as Deputy Managing Director of E. K. Cole Limited. While at the Ministry, Mr. Robertson was responsible for co-ordinating the production of vital electronic equipment for the defence programme. Many high-ranking members of the Ministry of Supply, including Sir James Helmore, K.C.M.G., the Permanent Secretary, attended a private luncheon party held in London on November 24th to bid farewell to Mr. Robertson. Mr. E. K. Cole, Chairman of E. K. Cole Ltd., and other Directors were present at the luncheon to welcome Mr. Robertson back to industry. First entering the radio industry in 1924, Mr. Robertson joined E. K. Cole Ltd. in 1930 and has been successively the Company's Chief Inspector, Production Manager and Works Manager. He was appointed to the Board of Directors in 1943 and was made Deputy Managing Director of the Company two years later.

Mr. N. C. Robertson

MR. W. D. OPHER

Mr. W. D. Opher, Member, of Vickers Armstrongs Limited, who was appointed a special Director in 1949 and a Director of the Company and General Manager of Southern Works and Director-in-Charge of Weymouth Works last year, has now been appointed General Manager of Elswick, Scotswood, Wakefield and Chertsey Works.

MR. J. E. BURNETT

Mr. J. E. Burnett, Associate Member, who for the past five years has been Works Director at S. E. Opperman Limited, has been appointed General Manager of Hanwell Engineering Company, Northampton. Mr. Burnett is a Member of Council and, until recently, of the London Section Committee. He was also a member of the Technical and Publications Committee.

MR. S. G. NIMROD

Mr. S. G. Nimrod, Associate Member, has been appointed to the Board of the Backer Electric Co. Ltd., Rotherham. Mr. Nimrod has been the firm's Works Manager for a number of years, and has been connected with Backer Electric since the firm started its activities.

Mr. S. G. Nimrod

NEW APPOINTMENTS

Mr. Louis Carter, Member, has resigned his Managing Directorship of Charles Churchill & Co. Ltd., South Yardley, and has taken over the Managing Directorship of the Cone Automatic Machine Company (Great Britain) Ltd.

Mr. A. J. Lund, Member, has been appointed Director of Simpson & Co. Limited.

Mr. C. H. Codling, Associate Member, has been appointed Production Methods Engineer in the Diesel Locomotive Works of Ruston & Hornsby Limited, Lincoln.

Mr. R. Gore, Associate Member, has resigned his position with Rolls-Royce Limited and has now taken up a position as Methods Engineer to the Sheepbridge Engineering Group, Chesterfield.

Mr. R. Jarvis, Associate Member, has taken up an appointment as Assistant Master, Grade B, in the Mechanical Engineering Department of the North Lindsey Technical College.

Mr. O. G. Mears, Associate Member, has joined the staff of Chippenham Technical College as Assistant, Grade B, in Mechanical Engineering.

Mr. D. H. Morgan, Associate Member, has recently taken up an appointment in Canada as Transformer Manufacturing Engineer in the Electronic Division of the Canadian Westinghouse Co. Ltd.

Mr. A. E. Nix, Associate Member, has taken up an appointment as Production Controller with the Millspaugh Group of Companies, Sheffield.

HAZLETON MEMORIAL LIBRARY

Members are asked to note that the Library will be open between 10 a.m. and 5.30 p.m. from Monday to Friday each week. Due to Meetings, the full facilities will not be available at the following times during this month :—

Thursday, 11th February from 11.0 a.m. Tuesday, 23rd February from 2.15 p.m.

It would be helpful if, in addition to the title, the author's name and classification number could be quoted when ordering books.

EXTRACTS FROM D.A.P.D. PROGRESS REPORTS FOR ISSUE TO INDUSTRY

Issue No. 1. June, 1953

The Library is in possession of several copies of the first issue from the Directorate of Aircraft Production Development, Ministry of Supply, of these Extracts.

The extracts, describing the latest processes and techniques in manufacture, are of a multifarious nature : it seemed better to assume that firms' executives would be interested in improvements in a wide field rather than a narrow one, because all innovations are liable to have a bearing on the future of a firm. Whilst a number of the processes are fairly well-known, especially to those engaged in the particular trade, they are included either because they are still subject to further development and therefore to be reported on further in due course, or for the benefit of those less familiar with a certain subject. D.A.P.D. intend to keep in close touch with the latest developments, to assist, financially if necessary, in bringing them to early fruition and to broadcast their usefulness as widely as possible.

Designers, as well as Production Engineers, will find these extracts of absorbing interest : they will be kept in close touch with the latest techniques and will therefore be able to make use of them in future designs. D.A.P.D. are in a position to arrange demonstrations, where more detail is required about any item.

The subjects embraced are as follows :—

1. Turbine and Compressor Blade Manufacture.
2. Casting Processes.
3. Die Manufacture and Maintenance.
4. Surface Protection and Finishing Processes.
5. Machining Processes.
6. Deburring Processes.
7. Foundry and Forge Shop Equipment.
9. Electrolytic Processes.
10. Skin Milling.
11. Changes in Manufacturing Methods to Cheapen Production.
12. Metal Forming, Extrusion, Rolling, etc.
13. Welding Techniques and Processes.
14. Inspection Equipment.

N.J.D.

REVIEWS

658 INDUSTRIAL ORGANISATION AND MANAGEMENT

" The Art of Administration " by Ronald M. Findlay. *Edinburgh, Oliver and Boyd*, 1952. 107 *pages*. 7s. 6d.

Although this book, written in the " pep talk " style of the American efficiency experts, adds nothing to existing literature on management subjects, it may have its uses as an introductory primer for the beginner. The serious student of administration is unlikely to gain anything from this collection of well-known facts and information. D.E.G.

681.2 INSTRUMENTS

" Copper in Instrumentation." (C.D.A. Publication No. 48.) *Copper Development Association, Radlett, Herts. Radlett, the Association*, 1953. 152 *pages. Illustrated. Diagrams.*

This recent publication of the Copper Development Association covers its field in three chapters under the main headings: Pressure and Strain—Responsive Instruments; Electro-Magnetic Instruments; and Temperature-Responsive Instruments.

In Chapter 1, the basic principles and materials are detailed, the materials including brass, phosphor bronze, nickel silver, monel, aluminium bronze, aluminium brass, cupro-nickel, silicon bronze, beryllium copper, K-monel and copper-manganese-nickel. Methods of jointing copper alloys are described, as are types of pressure-sensitive elements including Bourdon tubes, bellows, diaphragms and strain gauges.

Chapter 2 deals with the electro-magnetic properties of copper and copper alloys and the principles involved in their utilisation for instruments. Such components as coils, shunts, multiplier resistors, thermo-magnetic elements and copper-cuprous oxide rectifiers are described.

Chapter 3 includes information on the construction of various thermocouples, bimetallic elements and thermometers of the expansion type such as liquid filled, gas filled and vapour pressure operated instruments.

In addition to the above, the book contains an extensive bibliography for those wishing to read further on the subject of instrumentation.

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West Wales	H. P. Sanderson, I.C.I. Ltd. (Metals Division), Waunarlwydd, Nr. Swansea.
Wolverhampton	W. B. Pamment, Wolverhampton and Staffordshire Technical College, Wolverhampton.
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This Hoover brush typifies the high ductility of a Mazak die casting

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DIRECT DRIVE,
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We will supply the heads, or build special machines incorporating them, to meet specific requirements.

Regulated Power FOR DRILLING, REAMING, CENTRING, SPOT-FACING, HOLLOW MILLING.

CAPACITY OF UNITS—UP TO $\frac{5}{8}$" dia. DRILL

ELECTRIC MOTOR merely gives power to rotate spindle.

AIR PRESSURE provides power to move spindle forward.

OIL PRESSURE controls spindle movement for RAPID approach, controlled power feed.

CONTROLLED POWER FEED is fully hydraulic and independent of electric motor.

SPINDLE TRAVEL—4" maximum.

RAPID APPROACH. Rate—280 inches/minute (Constant) Travel. Adjustable 0 to full stroke (or any portion). Accurately adjusted to plus or minus .0005".

RAPID RETURN. Rate—200 inches/minute.

TRAVEL. From any spindle stop position.

AIR CONSUMPTION economical, available thrust up to 600 lb. at 80 p.s.i.

CAN BE MOUNTED IN ANY POSITION, for remote control, automatic or manual operation.

Learn more about these efficient units ● *Send now for free informative literature*

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GEAR STEEL CHIPS at . . .

. . . . . 1½ lbs. a minute

Actually the job took only 50 seconds: To produce the 7 inch PD gear (left) from the forged blank (right).

That's the kind of performance which you can get only from the Michigan **SHEAR-SPEED,** which cuts all teeth simultaneously.

The 6-pitch gear above, with its 42 teeth of 1¼ inch face width was cut with just 82 strokes of the **SHEAR-SPEED.** Metal removed in those 50 seconds weighed 22 ounces.

That's Speed! Speed which makes the **SHEAR-SPEED** the first gear cutting machine equal to Michigan gear finishing machines in productivity per machine hour. And the gears produced are equals in precision to gears cut in production by any gear cutting process.

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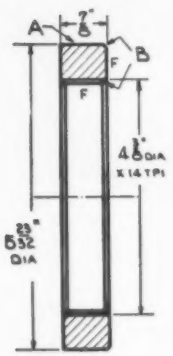
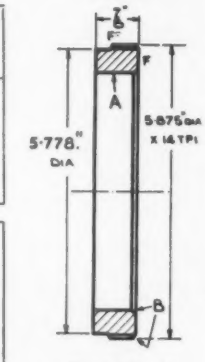


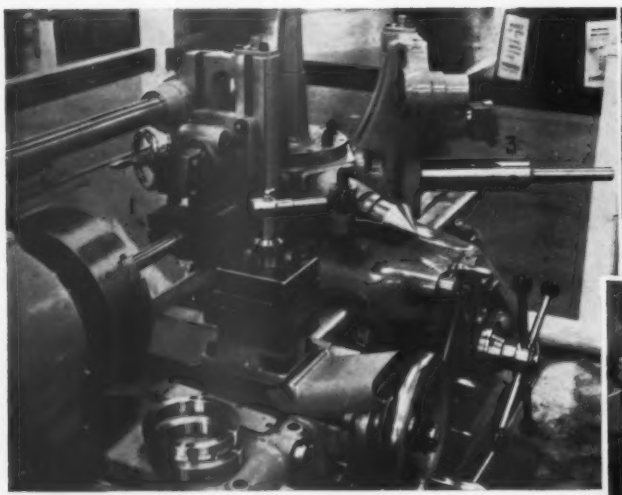
Part No. 1
Floor to Floor Time:
2½ minutes

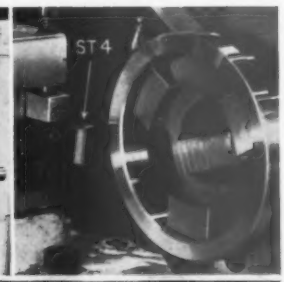
DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
Part No. 1					
Chuck on A	—	—	—	—	—
Face End Size Bore and Chamfer B	3	S.T.1	416	620	133
Screw Cut 4⅛" dia. × 14 T.P.I. (5 cuts)	—	Rear	416	475	14
Remove	—	—	—	—	—
Part No. 2					
Chuck Internally at A	—	—	—	—	—
Finish Turn 5⅞" dia., Chamfer B and Face End	1	S.T.1	416	640	133
Turn 5·778" dia.	—	S.T.3	416	640	133
Screw Cut 5⅞" dia. × 14 T.P.I. (5 cuts)	—	S.T.4	416	640	14
Remove	—	—	—	—	—



Part No. 2
Floor to Floor Time:
2½ minutes

LOCKING NUT **SCREWED RING**





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Capacity:
2⅛ in. dia. hole through spindle.
16¼ in. dia. swing over stainless steel bed covers.

Spindle:
Mounted in ball and roller bearings.

Powerful metal-to-metal cone clutches transmit power through ground gears.

Full details on request

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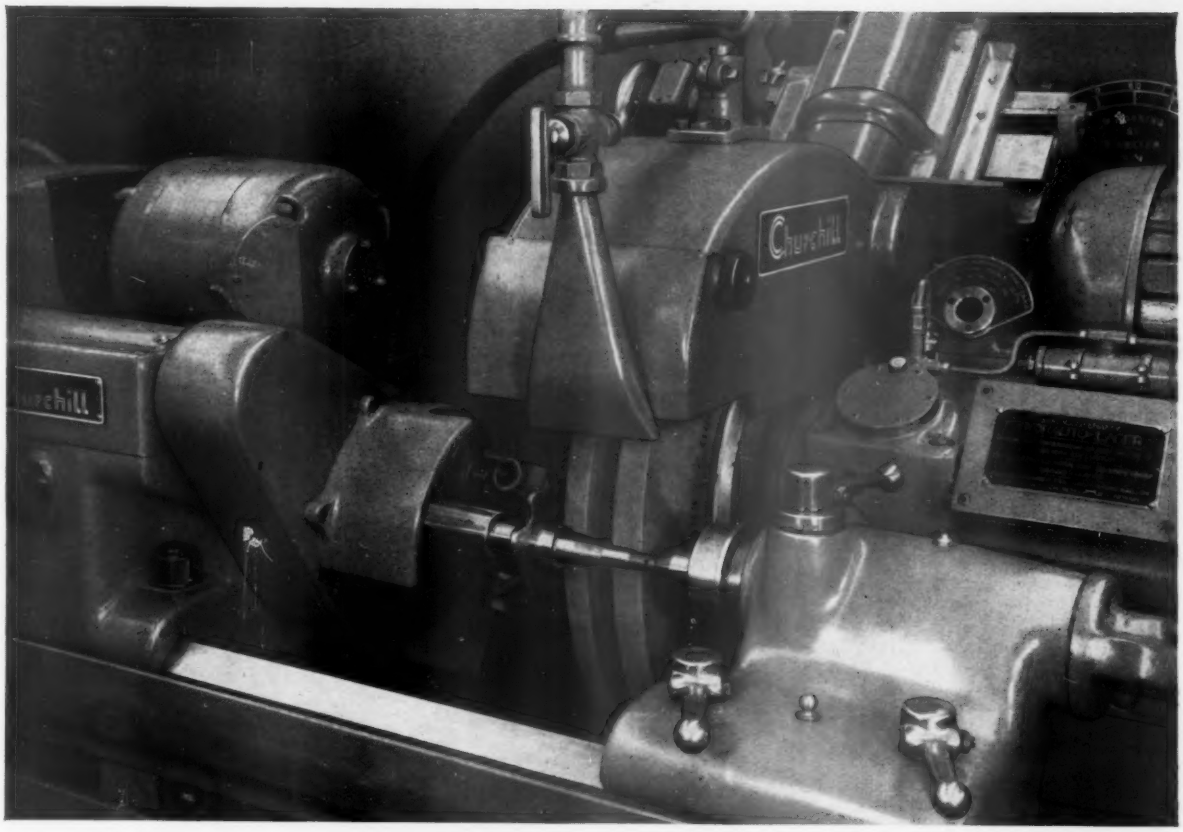
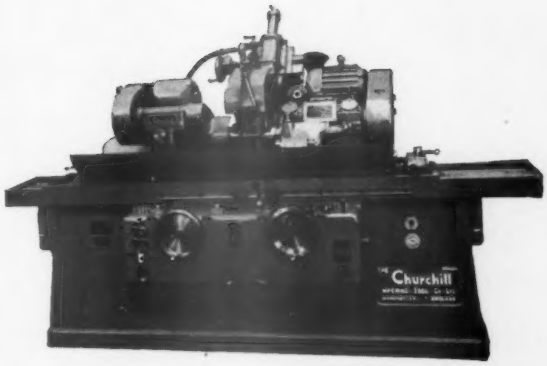


Churchill

THE CHURCHILL Model 'BW' 10" swing Plain Grinding Machine has a reputation for accuracy and high output. The machine shown here is equipped with twin grinding wheels for grinding two diameters simultaneously. The wheel forming device is mounted permanently on the back of the wheelhead and enables the wheels to be trued in correct relationship to the finished work diameters.

The 'BW' Machine can be supplied as a non-automatic or fully automatic Plain Grinder.



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Our long experience of Hole Production in all parts of the world enables us to produce the best machine to meet any particular requirement. Why not write us!
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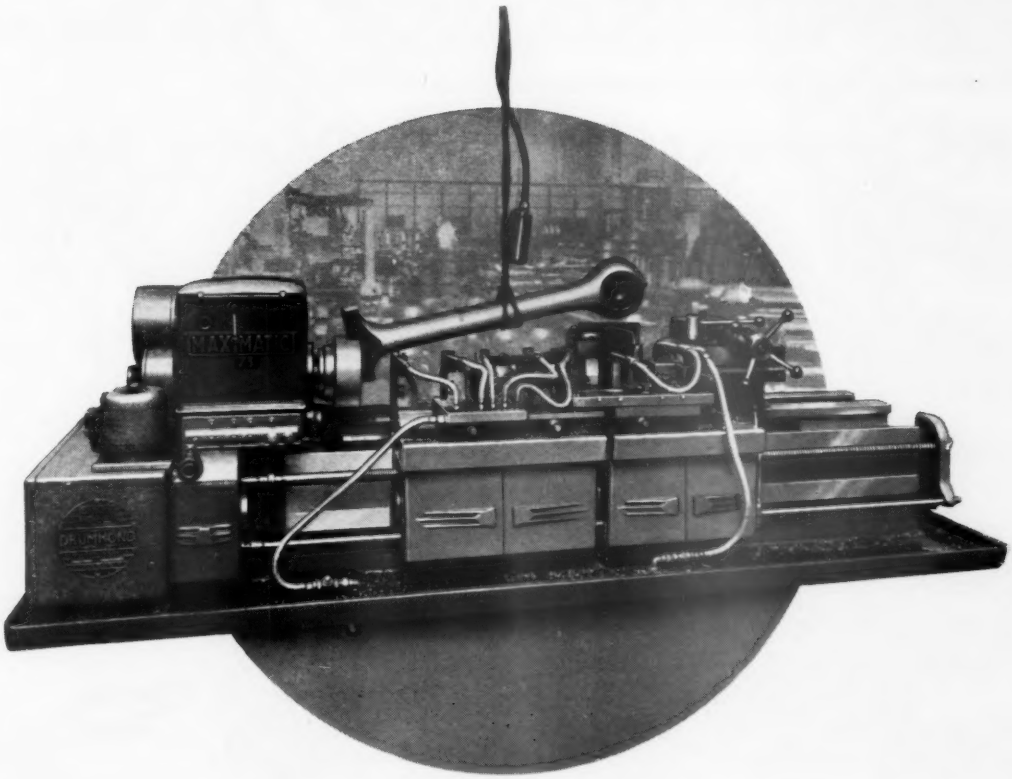

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AUTOMATIC MULTI-TOOL LATHES

Capacities : from 9 in. by 18 in. to 11 in. by 72 in.

Catalogue gladly sent on request

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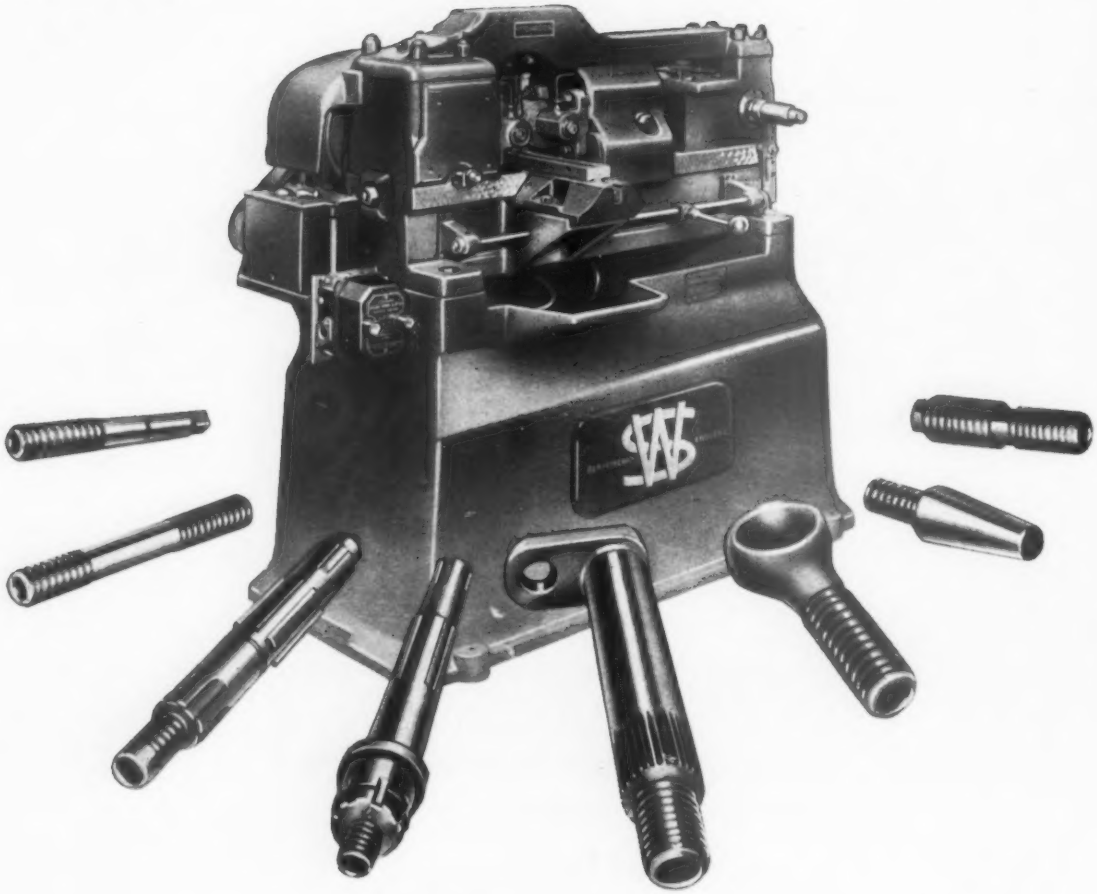
PITCHmaster WS for low cost rapid production by thread rolling



produces accurate rolled threads in High Tensile Steel

The PITCHmaster has been developed for the rapid production by thread rolling of components in high tensile steel. Regular and irregular shapes are thread rolled automatically—an important labour saving feature. *Send us samples of* **your** *high tensile components to be threaded and have the benefit of our experience in effecting cost-saving improvements.*

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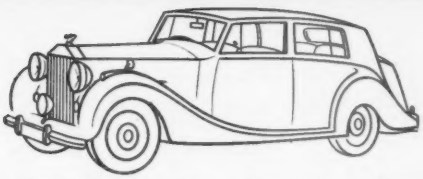
THINK ZINC



Almost as quickly as you can say the words "Think Zinc," molten zinc alloy has become the Stromberg carburettor you see here. This speed in production is just one reason why the automobile industry—like so many other industries—has adopted the zinc alloy die casting process. Other outstanding advantages are:—

SCOPE FOR DESIGNER · EXTREME ACCURACY · GOOD CORROSION RESISTANCE · STABILITY STRENGTH · LONG LIFE OF DIES · LITTLE NEED FOR MACHINING · LOW UNIT COST

The Association welcomes inquiries about the use of zinc alloy die castings. Publications and a list of Members are available on request. We suggest you write for our booklet "Zinc Alloy Die Castings and Productivity."

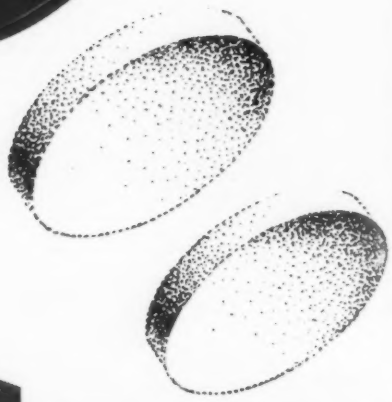
Zinc is now plentiful. There are no restrictions on its use.

ZADCA

ZINC ALLOY DIE CASTERS ASSOCIATION : LINCOLN HOUSE : TURL STREET · OXFORD · TEL · 48088

NEVEN TOOLS

speed the job!



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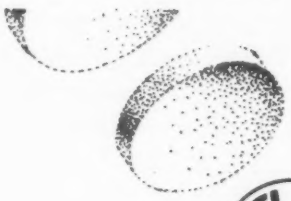

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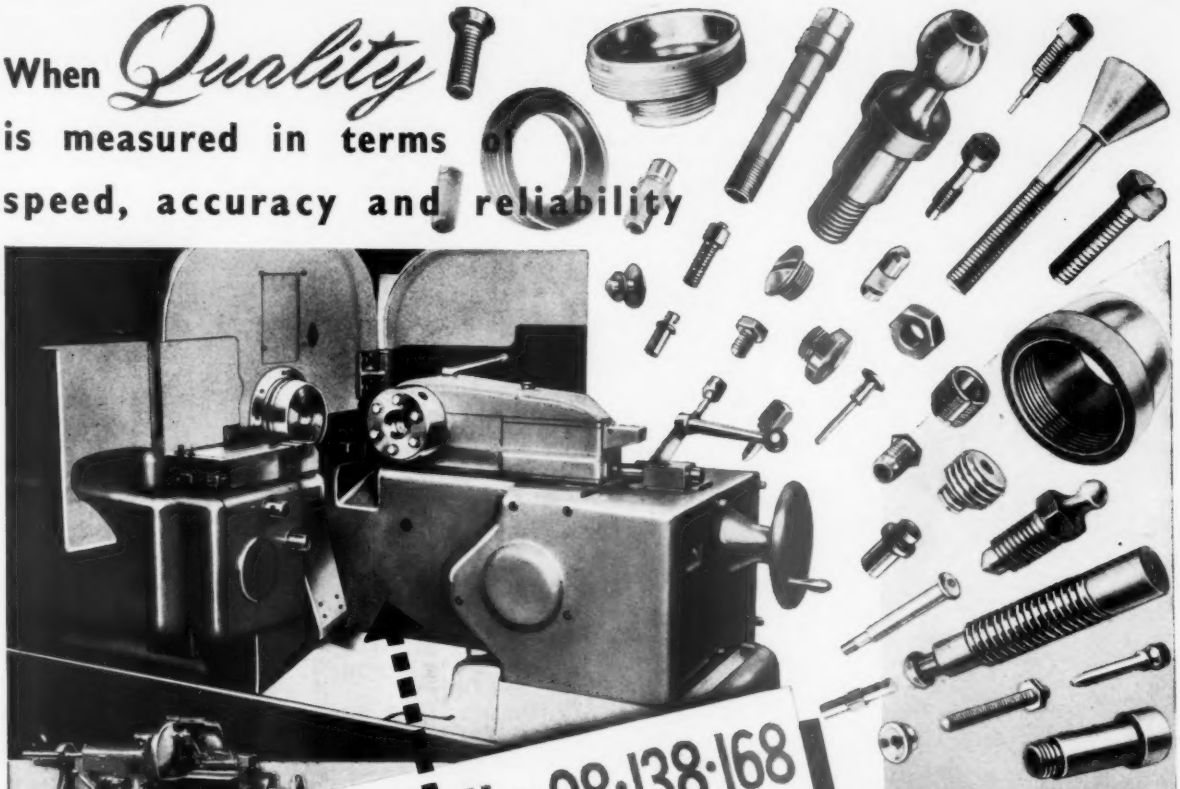
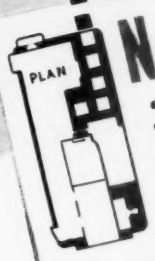
TELEPHONE 21164 (3 LINES) TELEGRAMS IMPREG GLOUCESTER

When *Quality* is measured in terms of speed, accuracy and reliability



No's 98·138·168



"L" TYPE—affording maximum chip clearance and accessibility in the operating area.
Capacities: 1", 1⅜", 2" dia. (standard)
Length turned: Long Stroke, 3"
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Spindle speeds: 1", 62 (2840 to 70 r.p.m.) *a*
or 75 (3135 to 32 r.p.m.) *b*
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or 68 (2230 to 25 r.p.m.) *b*
2", 60 (1260 to 69 r.p.m.) *a*

a Two changes of speeds in forward and reverse directions.
b One change of speed forward and one reverse or two speeds in either direction.

No.48

Capacity: ½" dia. (standard)
Length turned: Long Stroke, 1¼"
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Spindle speeds: 36 (6000 to 200 r.p.m.)

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Capacity: ¾" dia. (standard)
Length turned: 2"
Spindle speeds: 40 (4480 to 53 r.p.m.)

parts like these up to 2" dia. x 3" long can be produced consistently faster and more accurately on

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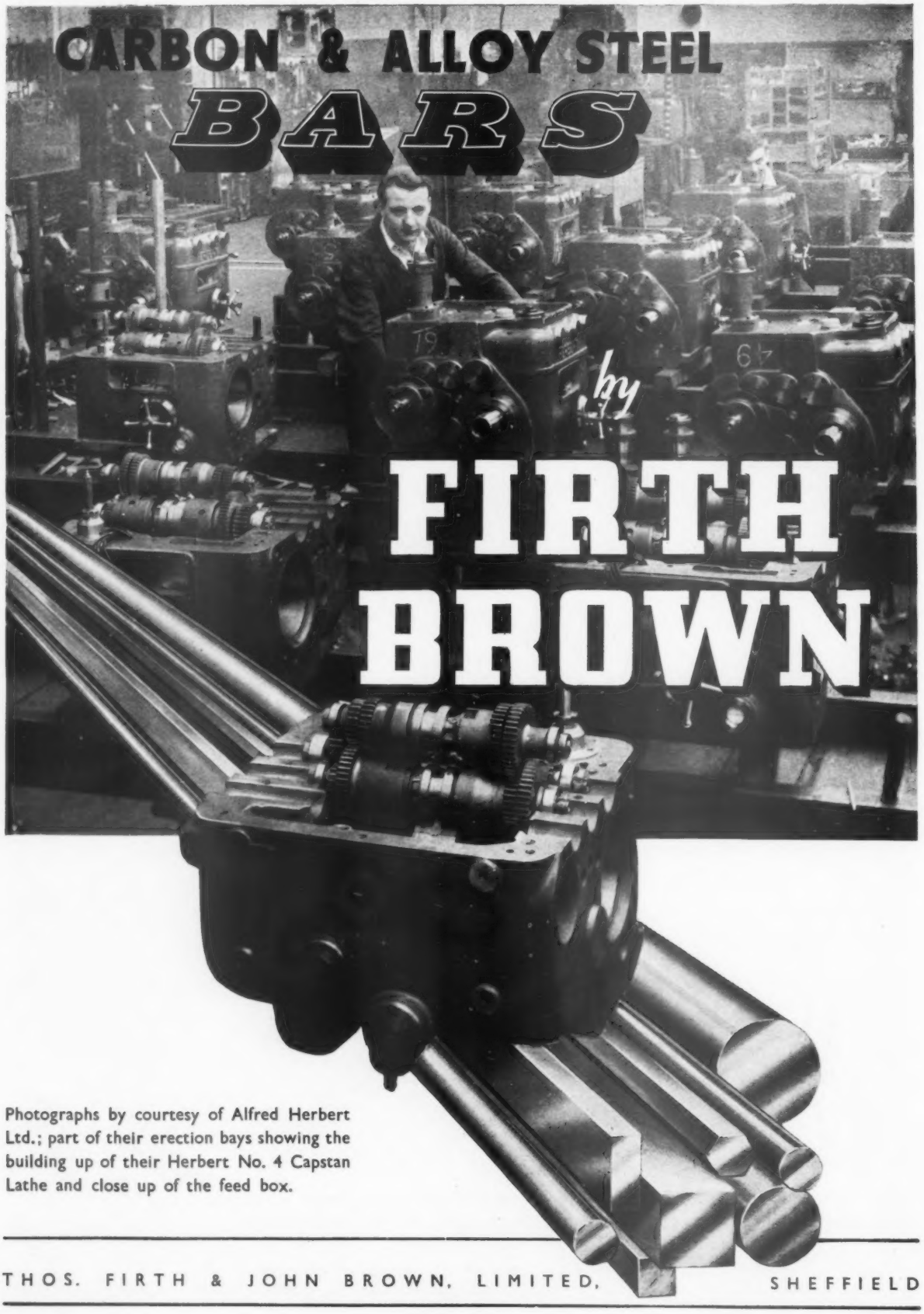
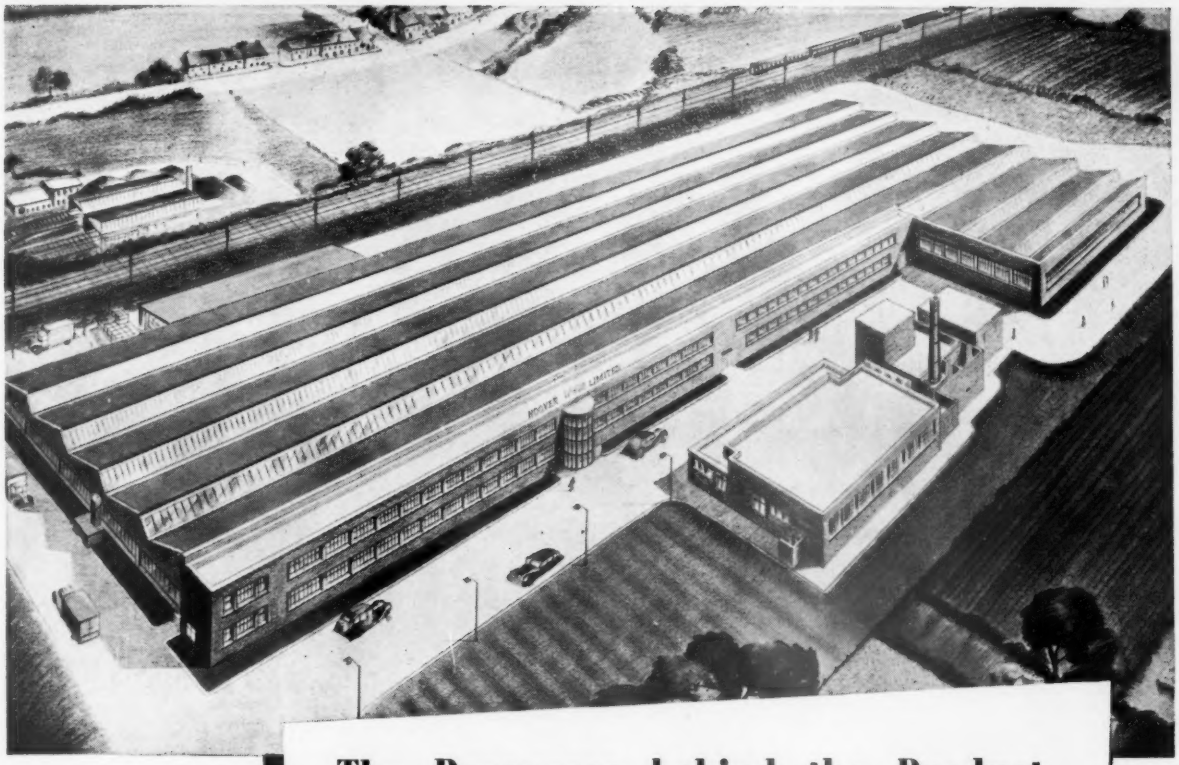


Photographs by courtesy of Alfred Herbert Ltd.; part of their erection bays showing the building up of their Herbert No. 4 Capstan Lathe and close up of the feed box.

THOS. FIRTH & JOHN BROWN, LIMITED, SHEFFIELD



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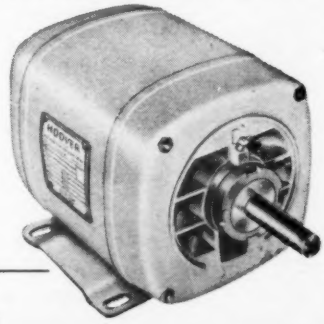

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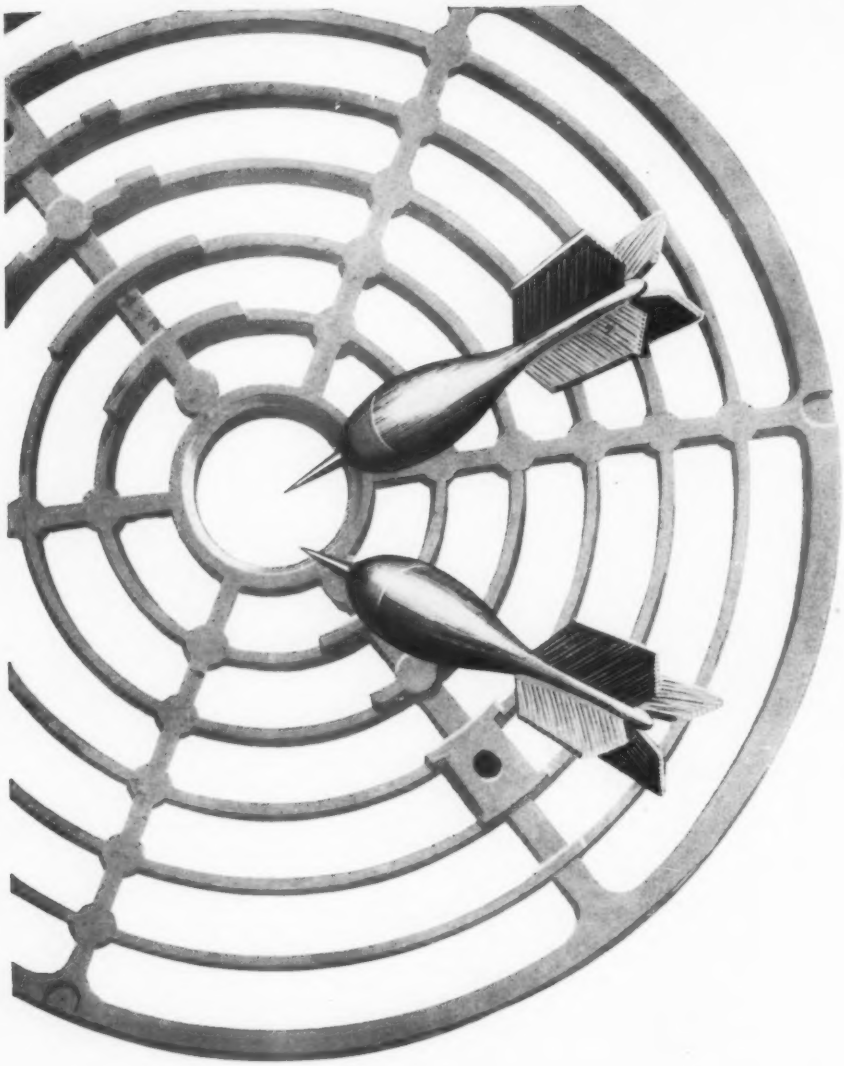

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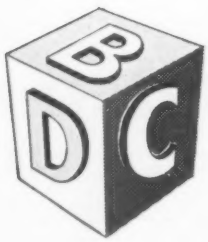
For safety? Every alloy we use in pressure die casting undergoes our spectrograph test. It is up to B.S.S.—or else!



the whole in one

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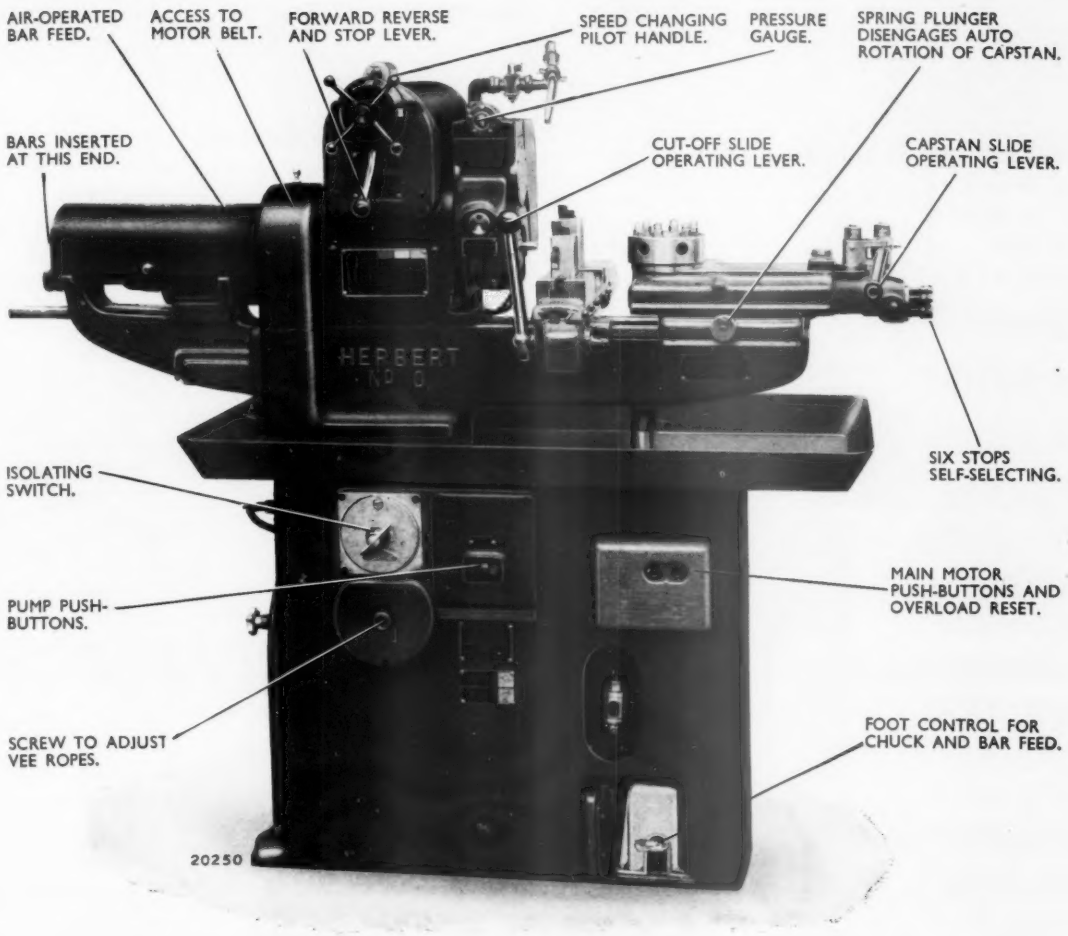

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This machine will give a HIGHER PRODUCTION than is possible on any other hand-operated Capstan Lathe.

When a workpiece is completed a light touch on the pedal opens the chuck and feeds the bar forward. On releasing the pedal the chuck grips the bar.

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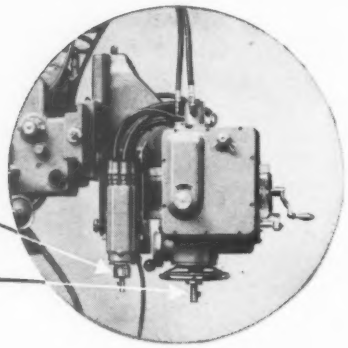
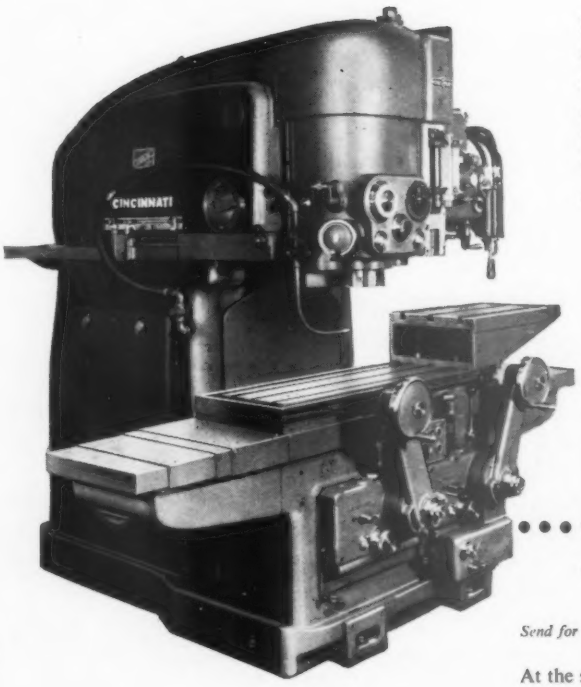


Cincinnati 16″ HYDROTEL



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HYDROTELS can also be used for conventional milling operations.

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At the same time, ask for BULLETIN M - 1620 - E describing the smaller 8″ x 18″ TOOL and DIE MILLING MACHINE.

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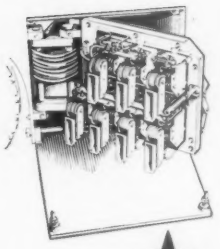
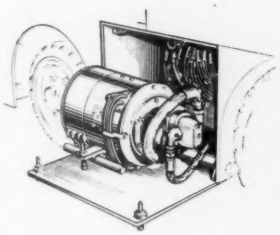
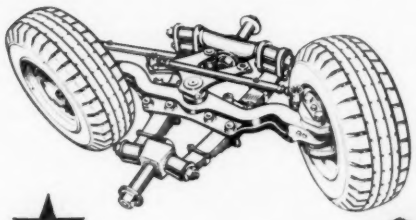
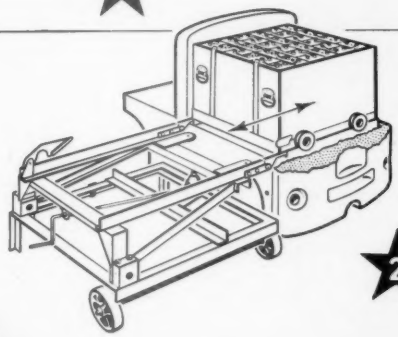




★1



★3



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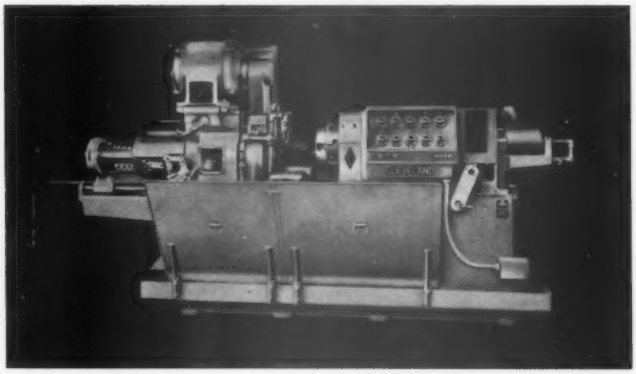

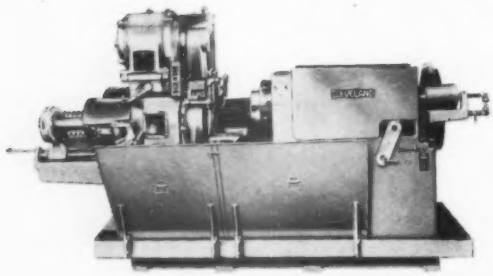

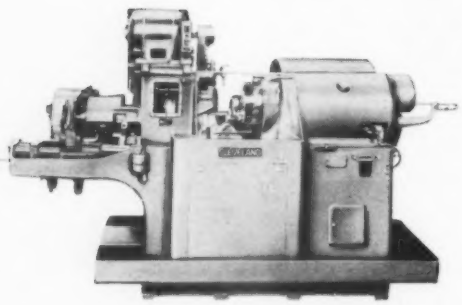

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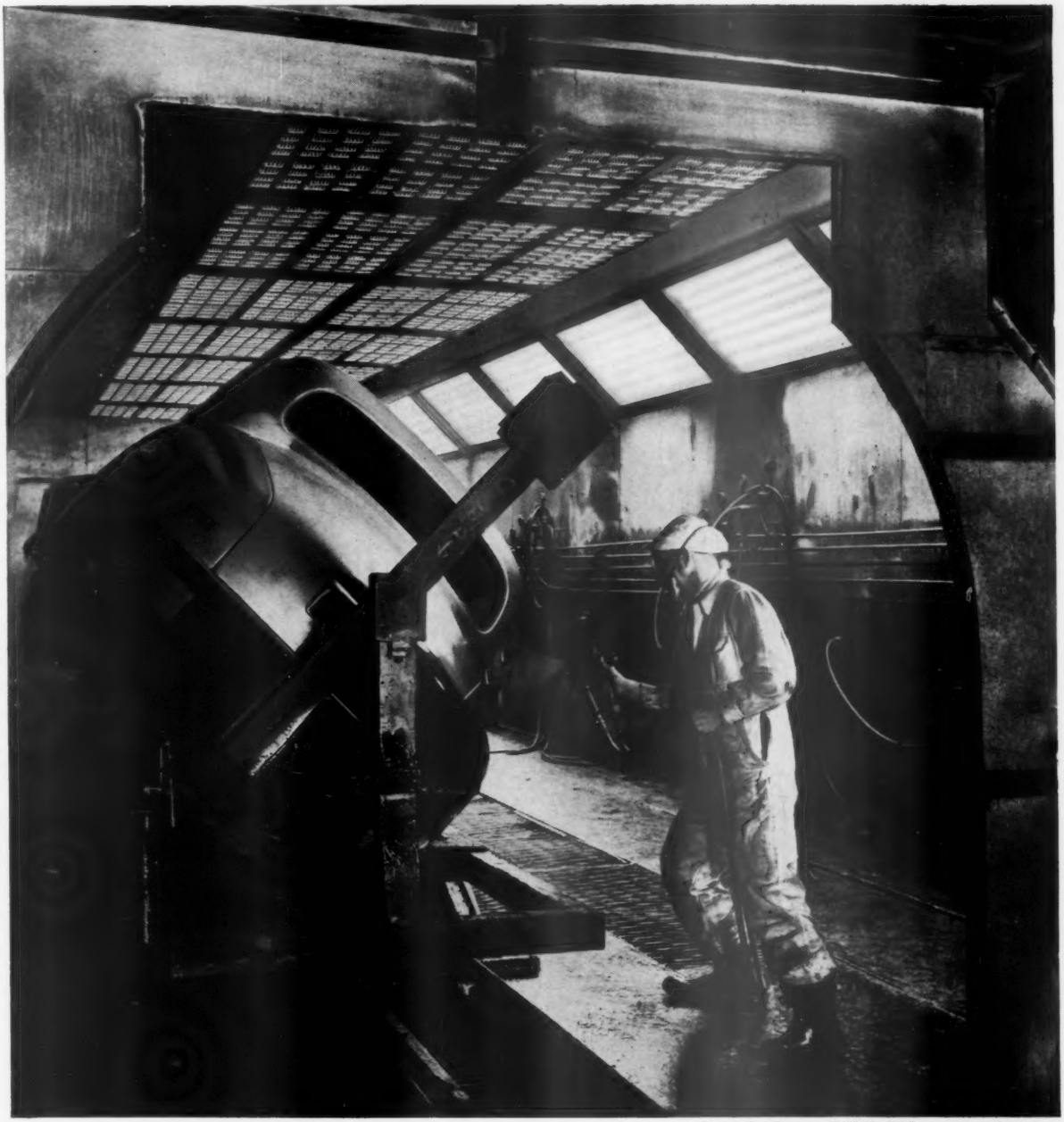

Rover Car Factory, Solihull. High intensity lighting in a body spray tunnel by fluorescent lamps in a glazed enclosure.

Tailored for the job

The lighting of many processes is vital to the smooth and rapid flow of work and to the quality of the finished product. For example, poor lighting could make a spray tunnel into a bottle-neck — each job taking a little too long, a little portion missed, a return to the spray line — and so the whole production line marks time. Whatever form it takes, good lighting not only helps to provide a satisfactory working environment but is an active production tool.

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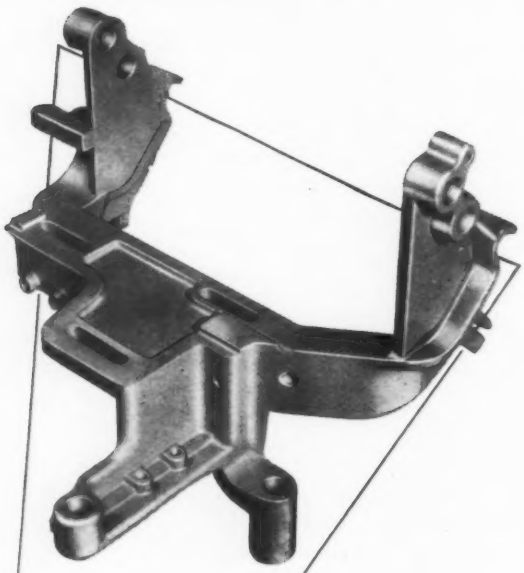

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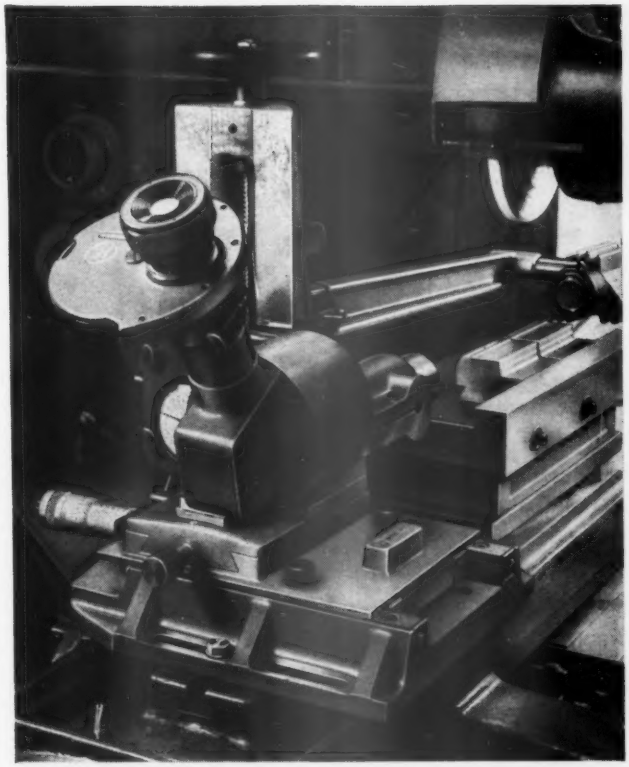

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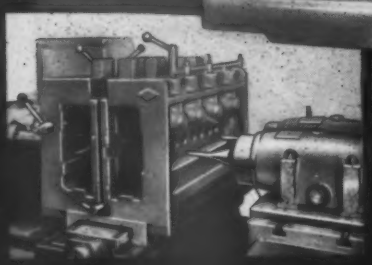

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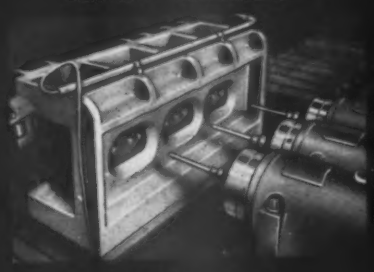

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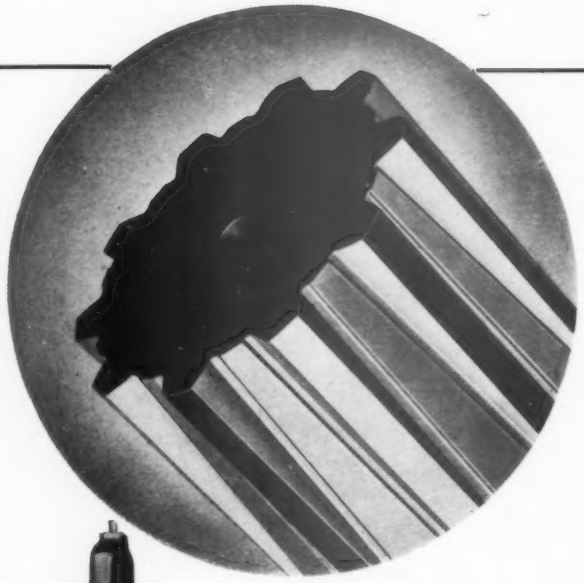

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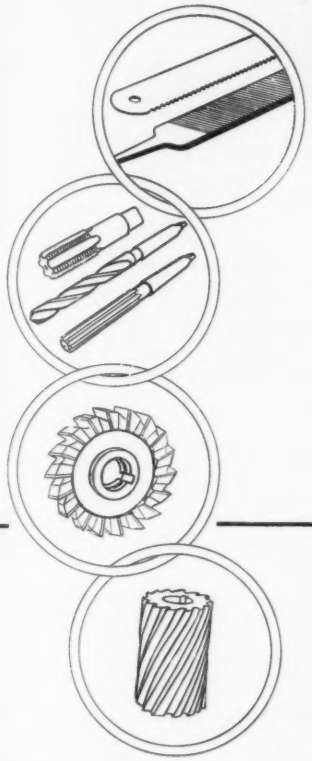

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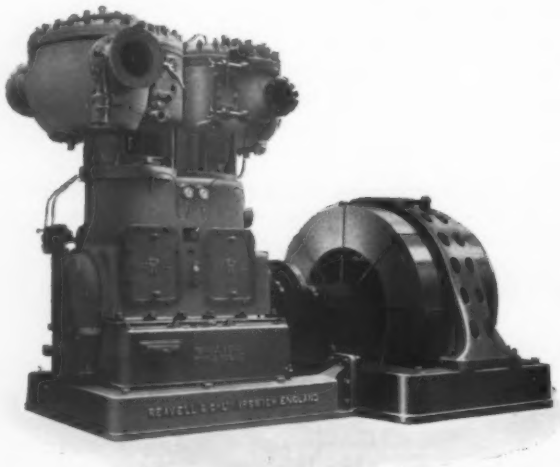

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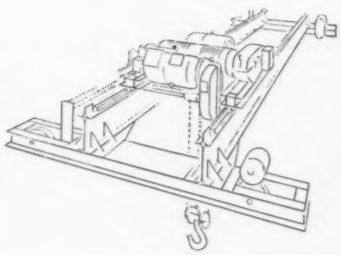
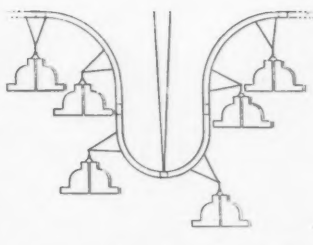


A KING *electric overhead crane*



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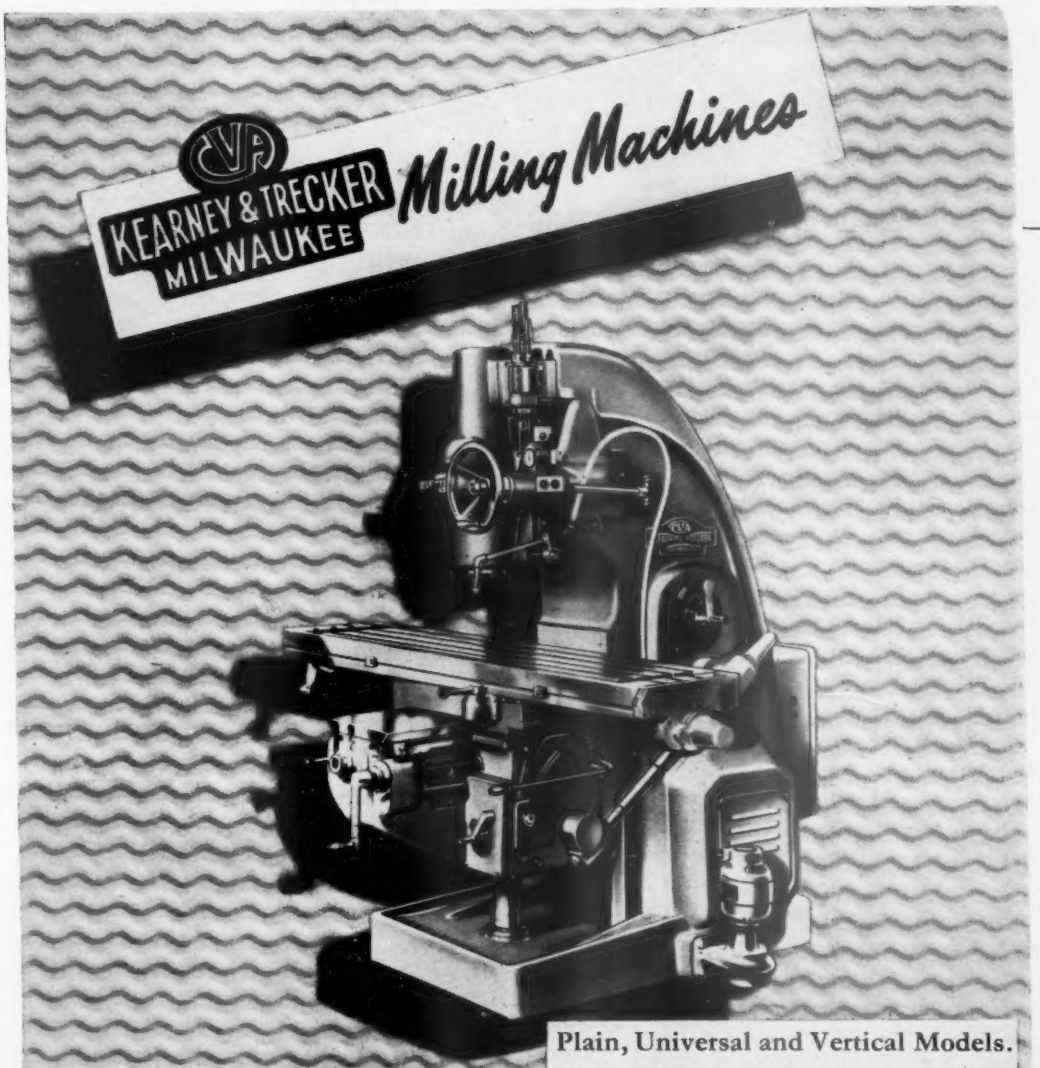

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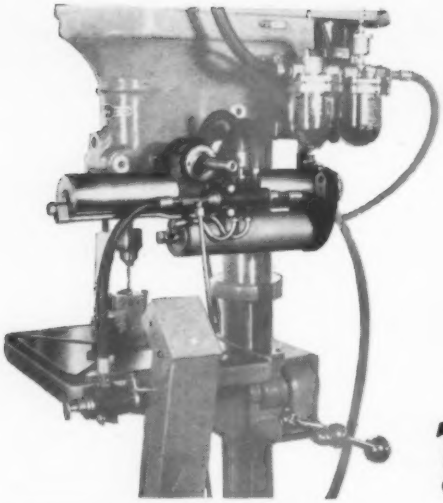

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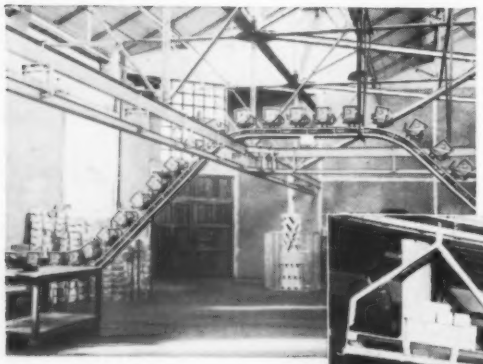

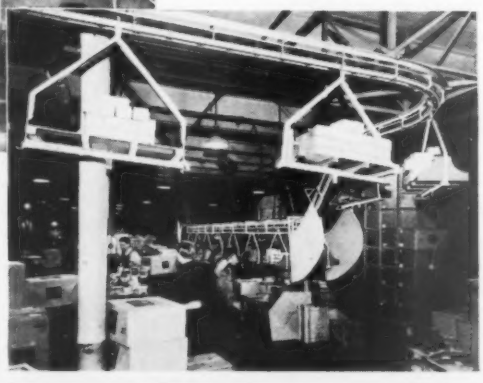

Above: The Teleflex dual-directional chain conveyor adapted to carry tins of biscuits.

Right: Overhead chain conveyor carrying cigarettes in packing and despatch departments at the factory of Messrs. W. A. & A. C. Churchman.

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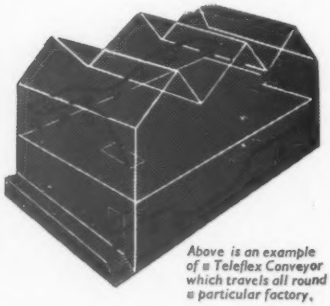

Above is an example of a Teleflex Conveyor which travels all round a particular factory.

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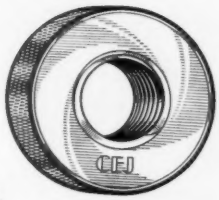

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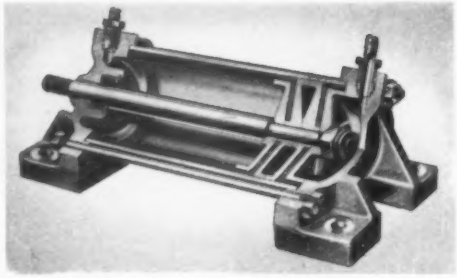

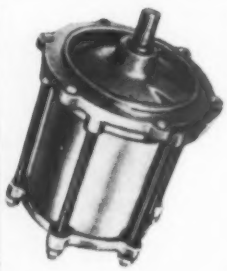

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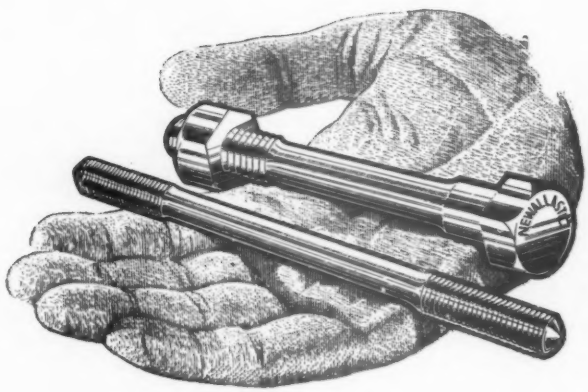

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In addition, the Torque Converter Drive slashes servicing down-time, and maintenance is reduced to a minimum.
Less driver fatigue
Greater dependability
Simplicity of control
Smoothness of operation
After-sales Service depots throughout the British Isles.
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Hardened all over. Accurately ground internally and externally.

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Oil toughened, with hardened tang. Ground externally.

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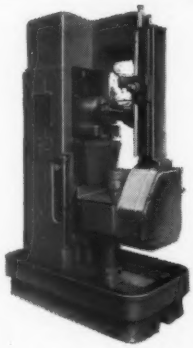
THE ONLY COMPLETE LINE FOR GEAR TOOTH PRODUCTION

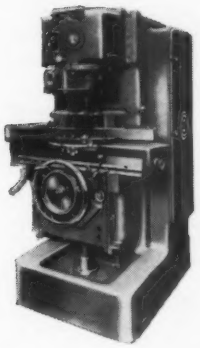
Hobbing

CHURCHILL CLEVELAND RIGID HOBBER

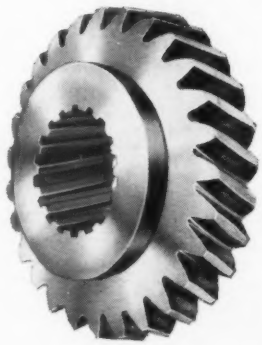


Shaving

CHURCHILL RED-RING DIAGONAL GEAR SHAVER



A typical example of accurate production . . .



COMPONENT: Automobile Gear—27 teeth—9·25 N.D.P.
Helix Angle 26°—13′ —15″
Face Width ⅜in.

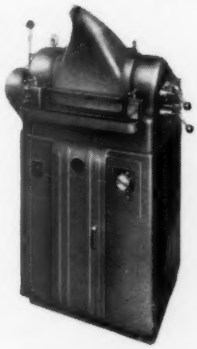
HOBBING: 3·5 minutes.

SHAVING: 40 seconds. Removing ·002/3in. from each flank.

SOUND TESTING: 40 seconds.

Sound Testing

CHURCHILL RED-RING GEAR SOUND TESTER



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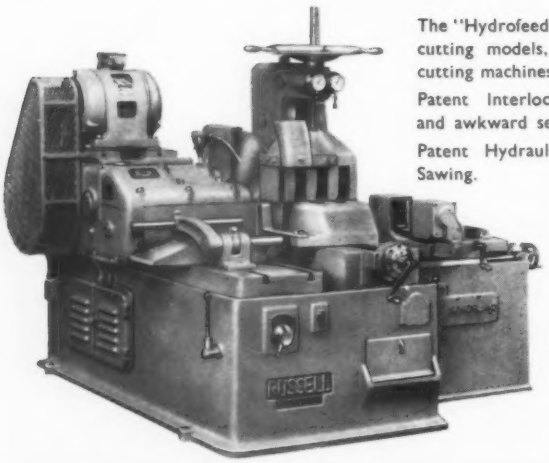

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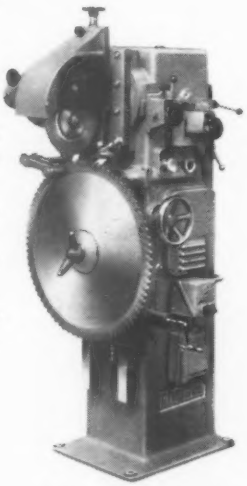
Patent Interlocking Vices can grip several bars and awkward sections.

Patent Hydraulic Circuit specially designed for Sawing.

Capacities up to 13½" diameter or 24" × 10" R.S.J.

'HYDROFEED' COLD SAWING MACHINE
Automatic bar feed.



SAW SHARPENING MACHINE
Capacity 11" to 48" blades

S. RUSSELL & SONS LIMITED • LEICESTER • ENGLAND

A PECO 5c DIE CASTER

'ironed out' the production problems

of this sole plate

These sole plates are being produced by the BRITISH DIE-CASTING COMPANY for MORPHY-RICHARDS LTD. The main illustration is of the production of these castings completely carried out on the PECO 5c Die-Caster

PECO machines have completely modernized the technique of Cold Chamber Pressure Die-Casting and with their unique feature, an electrical control, they are considerably in advance of other machines on the market. Four core-pulling connections, hydraulic ejection cylinder and bumper bars for mechanical ejection are fully interlocked, permitting operation in any sequence.

illustrated literature on the 2c and 10c Die-Casting Machines will be gladly sent on request.

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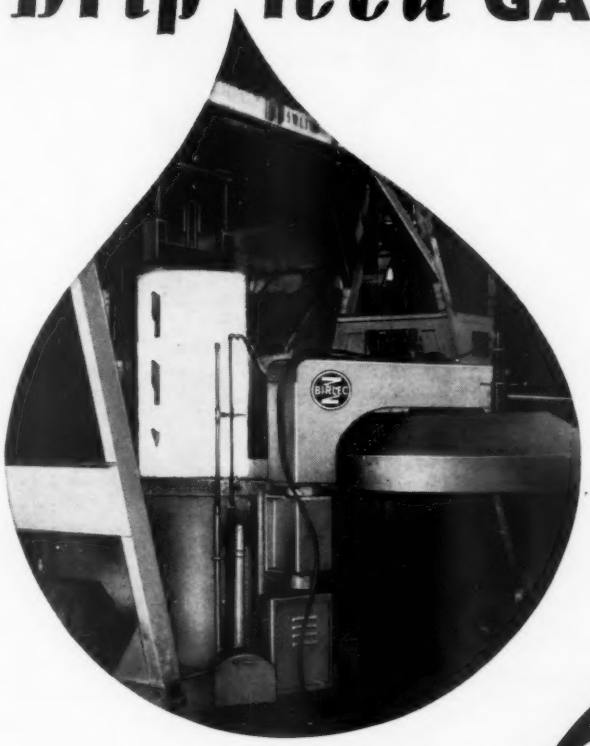
Drip-feed GAS CARBURISING



Birlec pit gas carburisers can now be supplied with the "drip-feed" atmosphere generation system, as an alternative to using a separate generator and enriching the processed town's gas with butane, methane, etc. In the "drip-feed" furnace a suitable organic liquid is dripped into the heated charge chamber where it vaporises and cracks to form the carburising gas. The liquid comprises ingredients readily obtained from chemical suppliers at a cost not exceeding 10 - per gallon.

Illustrated are two 65 kW pit gas carburisers using "drip-feed".

with STANDARD PIT GAS CARBURISERS

In instances where there is little floor space available, "drip-feed" may be preferred to the use of an external generator. It is also slightly cheaper in capital cost, although this advantage is ruled out if three furnaces (which can utilise the same generator) are installed. On running costs there is little to choose between them and both show considerable economies over the pack carburising process. Depending on the size of furnace used, charge handled and case-depth required, the carburising cost in standard Birlec pit furnaces varies between 1d. and 1½d. per lb.

BIRLEC LIMITED

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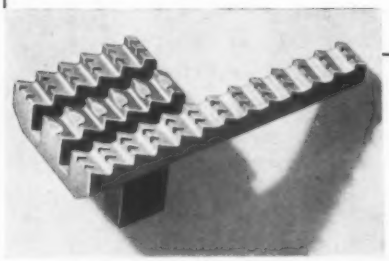
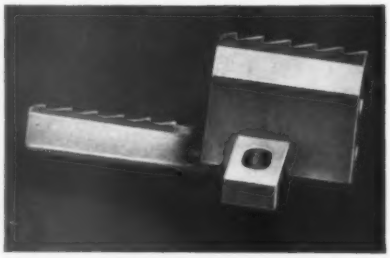
If the Production Director sees these he will want to change a thing or two



Two views of a feed mechanism in a high chrome molybdenum vanadium tool steel.

Coupling Hub in Cr-Mo-Va tool steel.



Two views of a helmet clip in stainless steel.

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The castings illustrated are in ferrous metals and are examples from recent jobs which called for special characteristics not obtainable at reasonable cost by any other method. If you have a similar problem bothering you we would welcome the opportunity of seeing the drawing, or better still, the prototype—so that we can quote for the job. Intricate design or obdurate metal *(or both)* it's all one to us.

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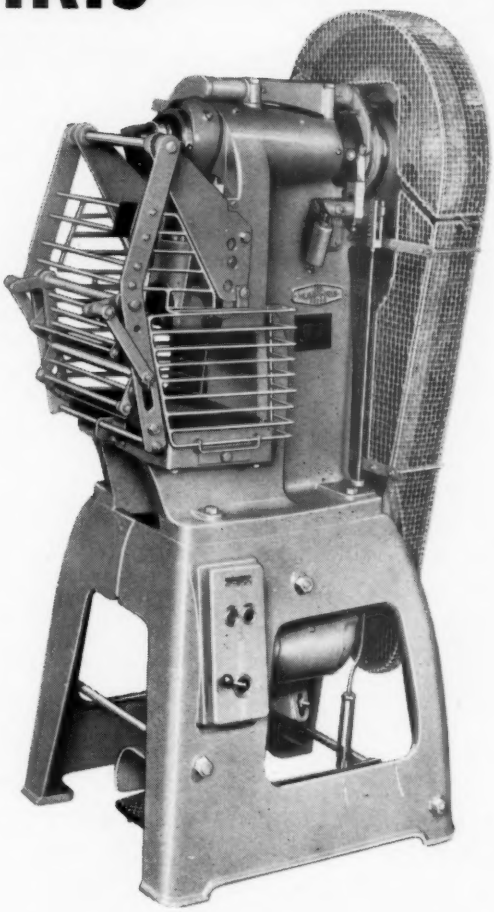

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Bratby

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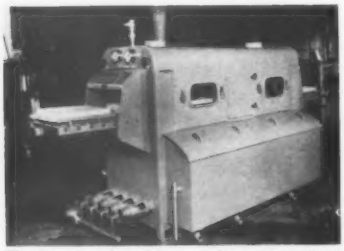
INDUSTRIAL CLEANING MACHINES

can be designed to meet your particular cleaning problems

This illustration shows a machine cleaning crank cases in the production line. It is equally capable of cleaning small parts in baskets.

A power driven conveyor system is employed with this cleaning machine for ball bearings.



Trays carrying the work are pushed through on a roller conveyor by hand in this cleaning installation.

Whilst offering a very wide variety of standard cleaning equipment, it is BRATBY policy, wherever possible to design the machine to meet the particular cleaning problem. Careful study of each individual problem ensures maximum efficiency and economy of the plant in operation. The illustrations show but a few of the specific types of Cleaning Machines designed by BRATBY for individual needs.

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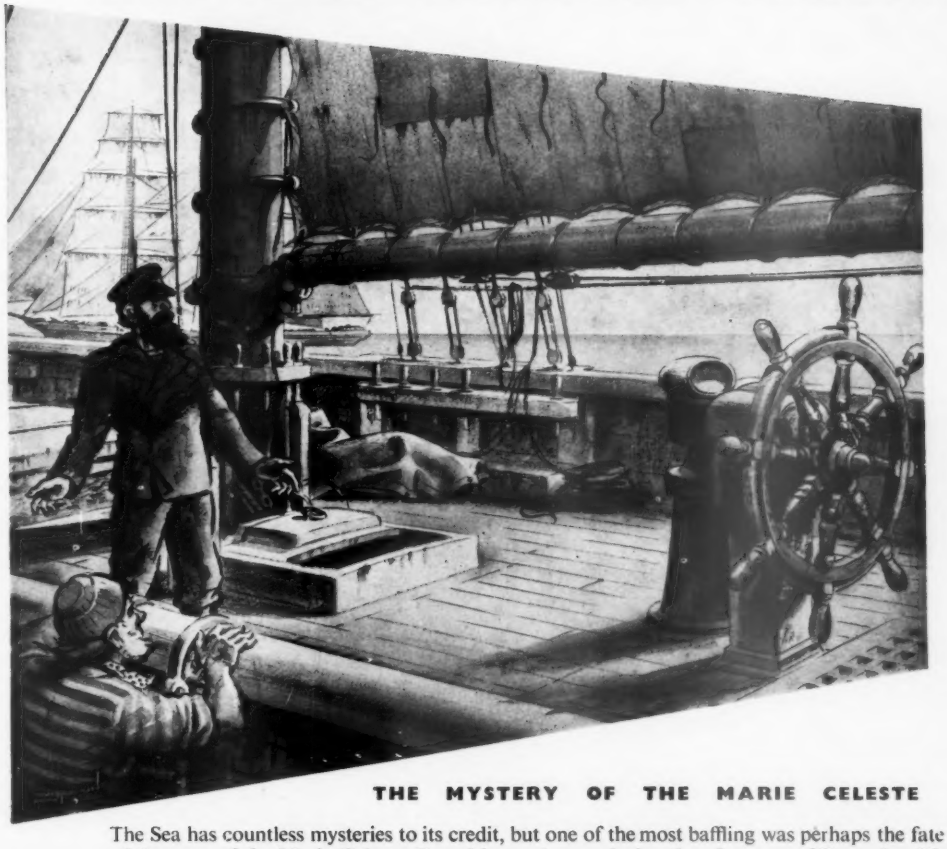

THE MYSTERY OF THE MARIE CELESTE

The Sea has countless mysteries to its credit, but one of the most baffling was perhaps the fate of the crew of the Marie Celeste. Found in a calm sea during the afternoon of December 5th, 1872, the ship was mid-way between the Azores and the coast of Portugal. When Captain Morehouse, commander of the brig Dei Gratia sailing out of Nova Scotia overhauled her, she appeared perfectly normal. Her sails were set and filling to a light northerly breeze and Captain Morehouse recognised her as the ship which he had seen loading in New York, and which had left three days before him. He had had a drink or two with her Master, an old acquaintance of his named Briggs, so it was only natural that he should sail close, and hail the Marie Celeste. Captain Morehouse was surprised at receiving no acknowledgement and fearing something was wrong, sent his Mate Oliver Deveau to investigate. There was no sign of the crew, no sign of violence and the barrels of alcohol in the hold were untouched. Only a hatch was out of place, upside down and a half drawn cutlass with a few drops of blood lay beside it. The galley was in perfect order, a harmonium in the cabin had been played recently and the log had been made up to November 23rd. Seamen's chests were untouched and everything appeared neat and tidy certainly showing no evidence of bad weather. In spite of many theories, it remains to this day one of the world's great unsolved mysteries.

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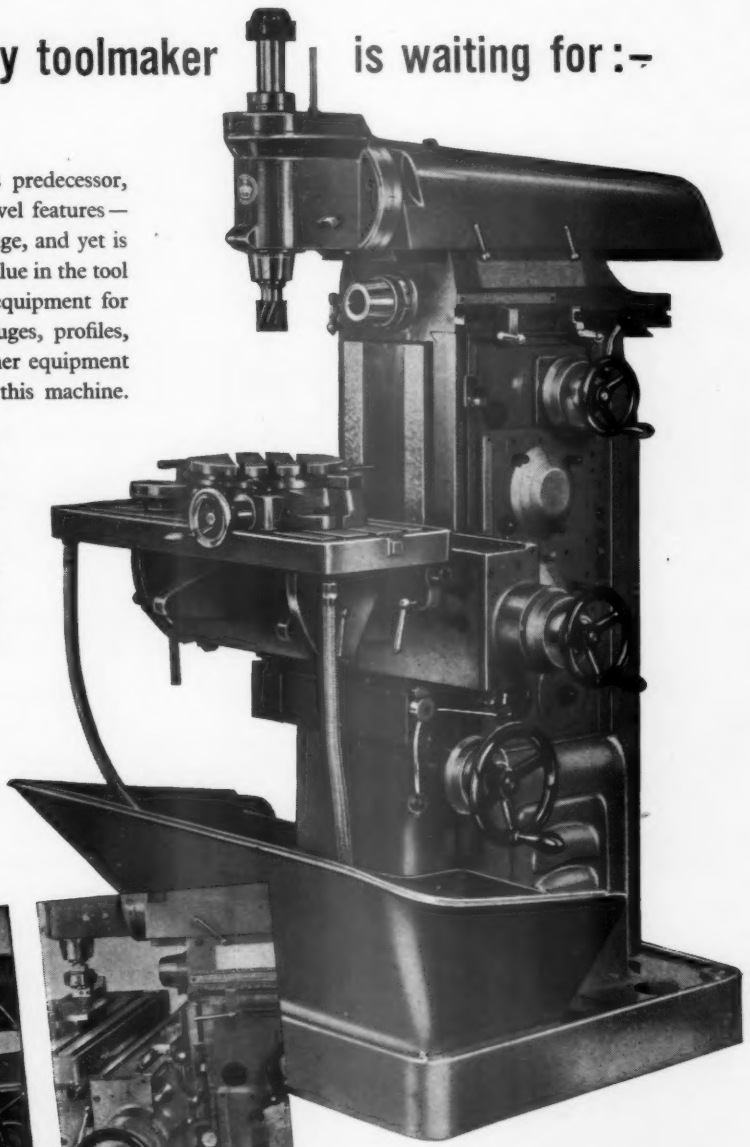

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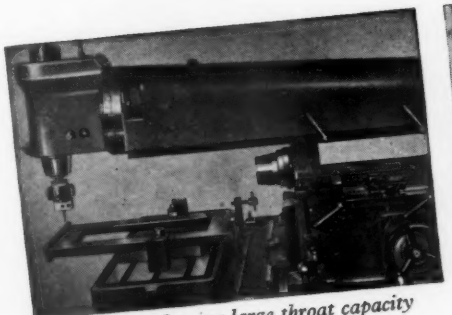

Jig boring showing large throat capacity

Close to column jig boring

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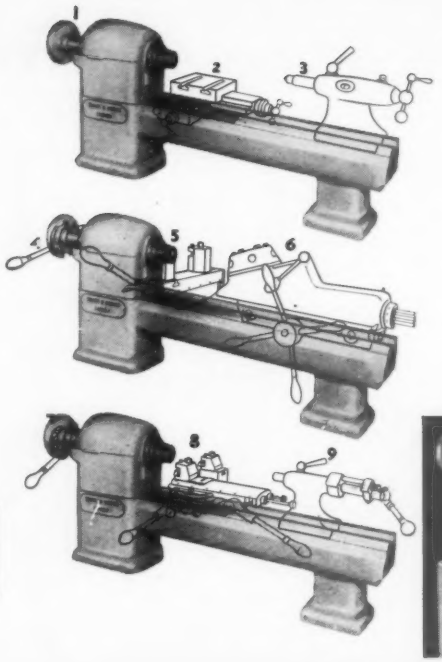

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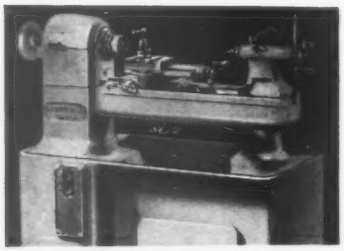

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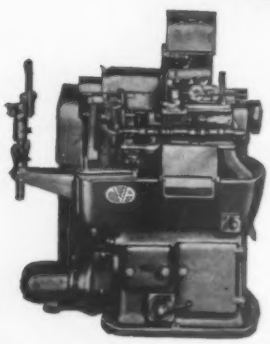

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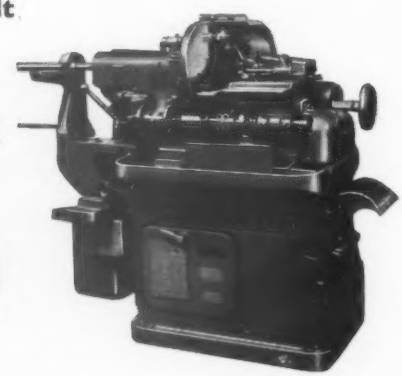

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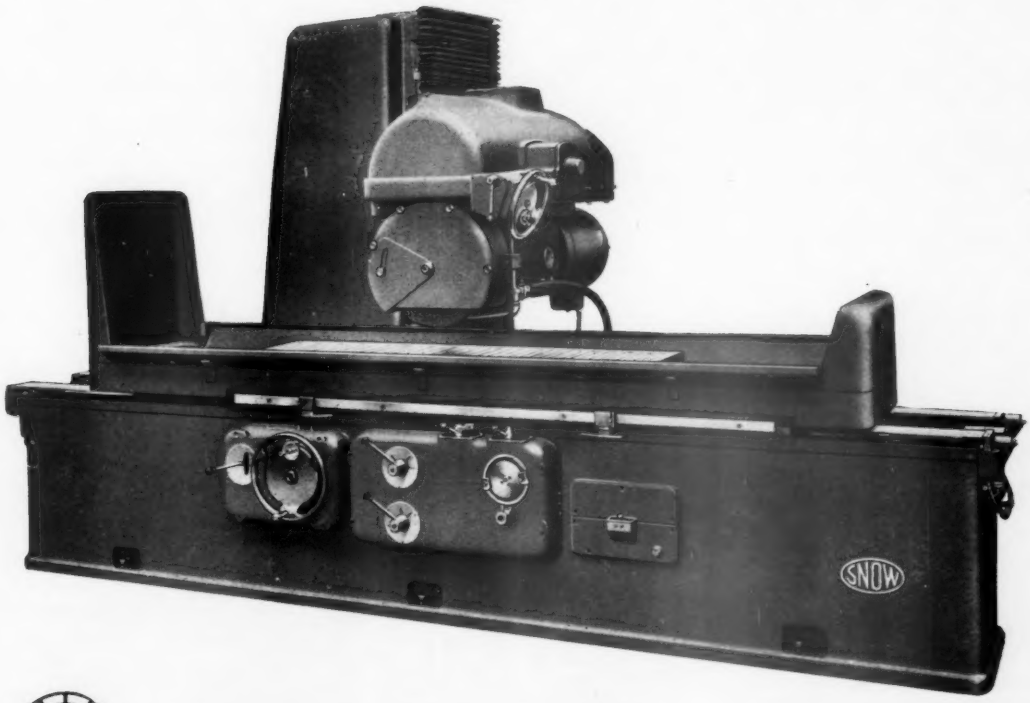

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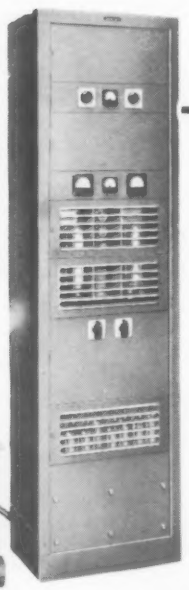

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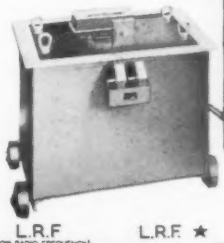

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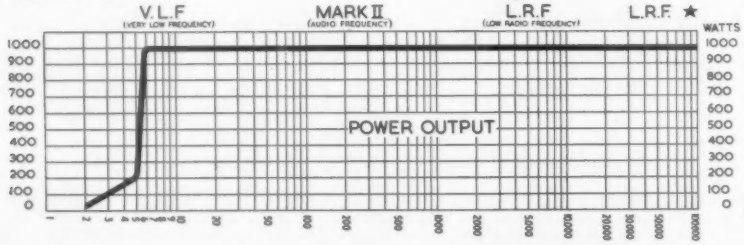

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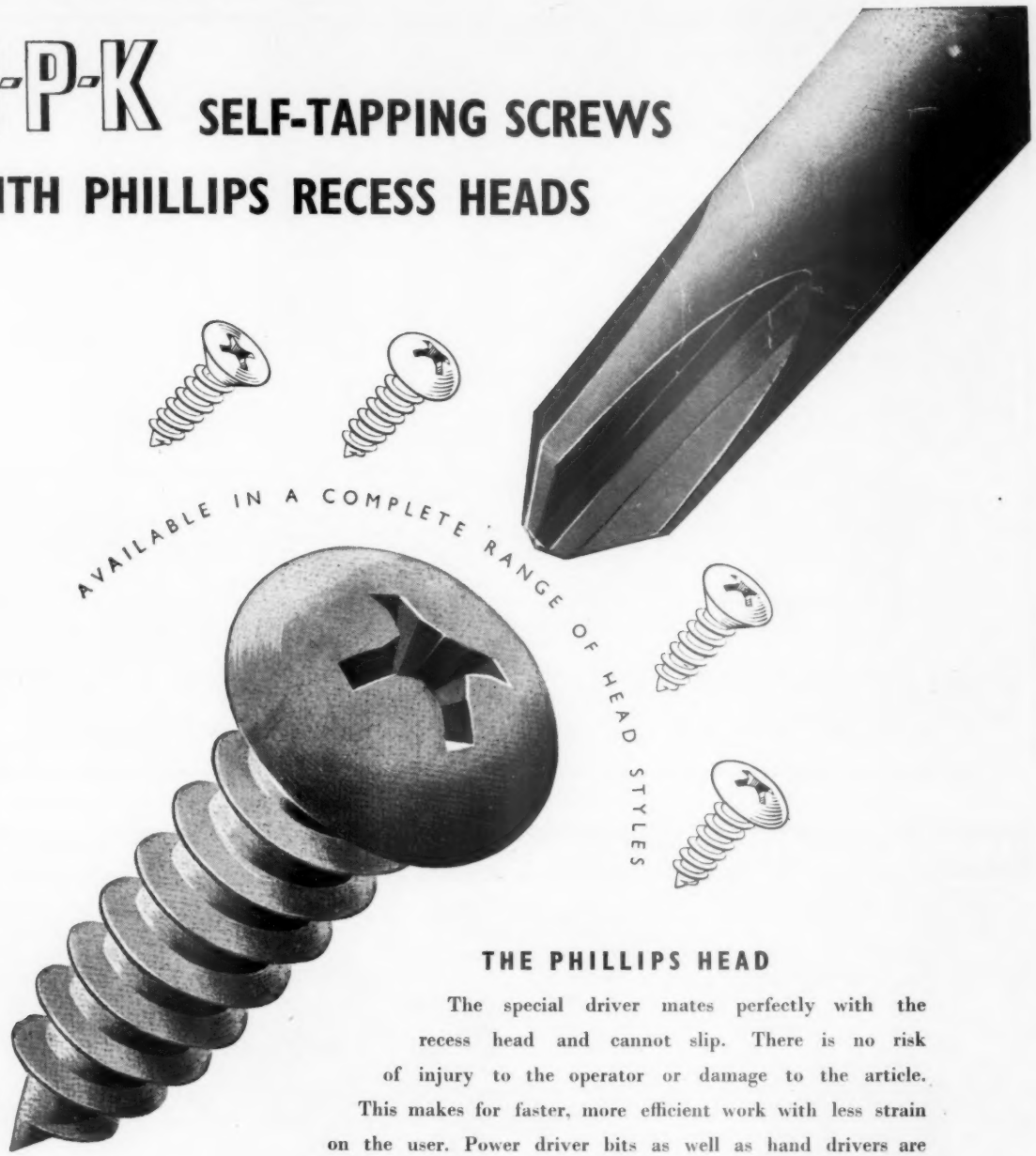

THE PHILLIPS HEAD

The special driver mates perfectly with the recess head and cannot slip. There is no risk of injury to the operator or damage to the article. This makes for faster, more efficient work with less strain on the user. Power driver bits as well as hand drivers are available for Phillips Heads.

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The hardened threads of Nettlefolds Parker-Kalon screws cut corresponding threads in drilled, formed or moulded holes. There is no need for tapping, tapping plates, inserts, clinch nuts or lock washers. N.P.K. screws simplify assembly methods and make stronger fastenings.

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SCREW DIVISION: BOX 24, HEATH STREET, BIRMINGHAM 18

GKN

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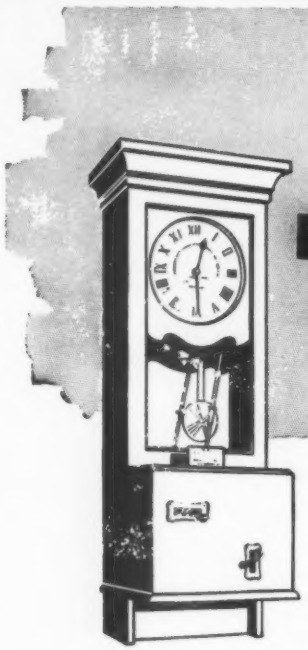

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The Gledhill-Brook Company was intimate with the early problems associated with the design and production of time recording machines, and was first in producing efficient electric impulse recorders with accurate timekeeping free from dependence on electric frequency or external influence. Wages and cost methods have a time basic—that is where we are concerned to help. A large number of time recording models is now available covering most of the known needs for wages and labour cost control. One of industry's immediate needs is the reduction of waste—the waste of time that costs money.

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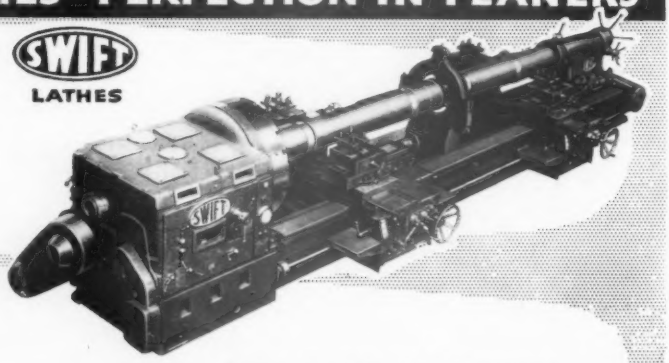

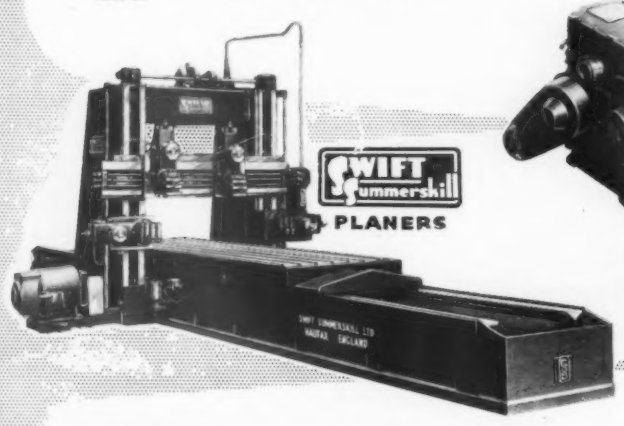

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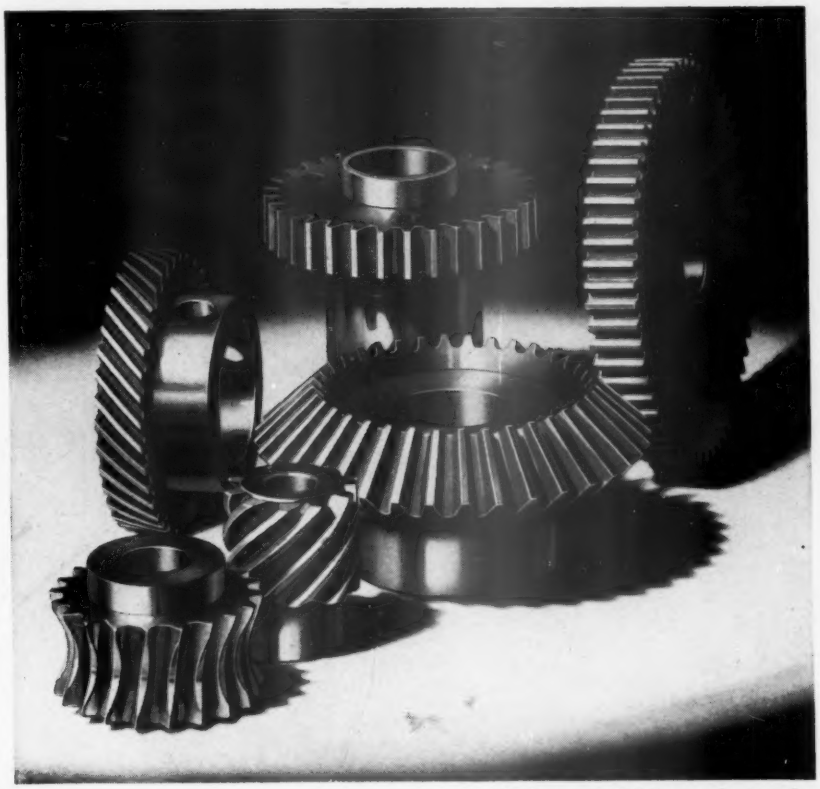

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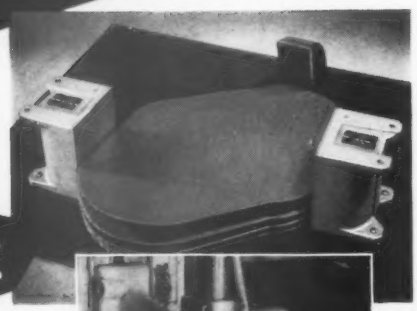
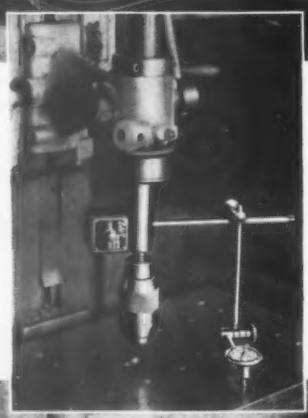
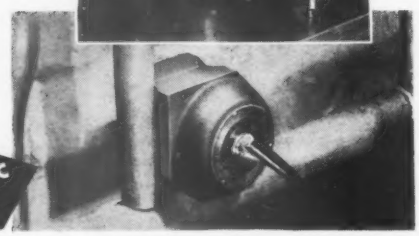


Magnetic Floaters



Magnetic Base



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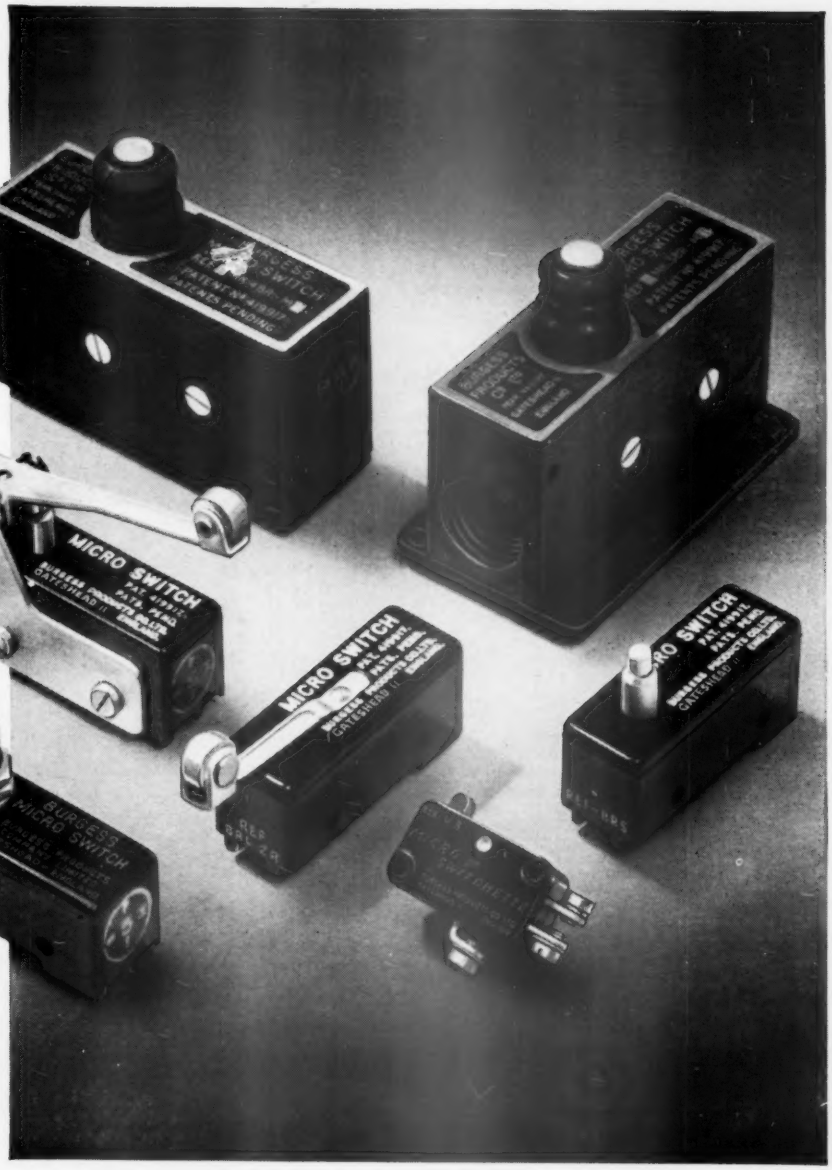

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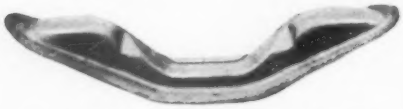
A MODERN MANUFACTURING SCIENCE

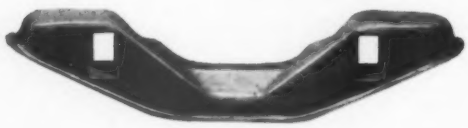
These illustrations show the six stages in the production of a particular pressing, the number of pressing operations being dictated by the thickness of the material and the depth of the designed shape. Simple pressings require only one drawing operation after the flat shape has been blanked from a sheet.

Pressing is a process of manufacture which holds enormous possibilities for the Designer and the Engineer. By means of modern power presses and expertly contrived dies parts of simple or complex shape can be produced in large or small numbers, at a cost, which generally compares favourably with other methods of manufacture and is not infrequently much lower if a pressing is skilfully designed.



The essence of the process is design. It is open to the Designer to use metal of modest thickness which by skilful manipulation can be formed into a shape through which the forces acting upon a component are resolved along the planes of maximum resistance.

The services of an experienced representative are at the disposal of any interested Engineer who wishes to talk about pressings, and a 'design study' to relate the functional and process aspects of design will readily be undertaken in order to demonstrate the possibilities of the process.



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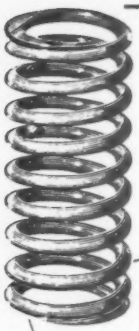

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what is **natural frequency?**

Natural frequency is the term for the number of complete vibrations made in a period of a minute by the coils of a spring when, after an initial disturbance, it is vibrating freely.

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WHEN ACCURATE 'FINISH' IS VITAL—

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makes it easier for you

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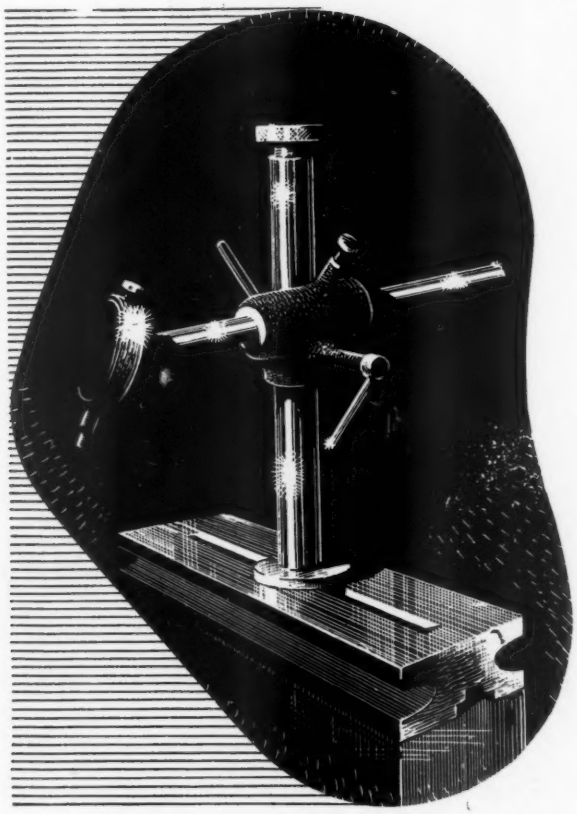

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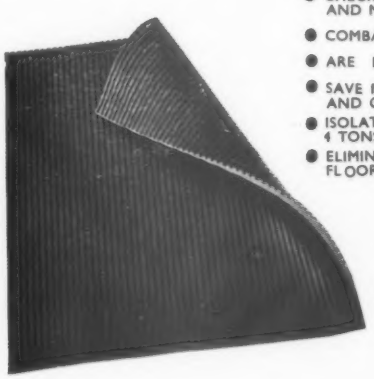
Improve VULCASCOT REG. TRADE MARK *Production!*



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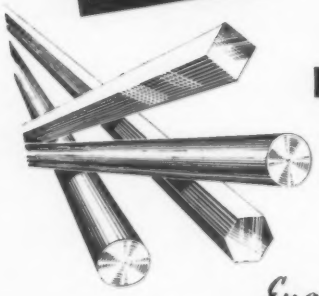

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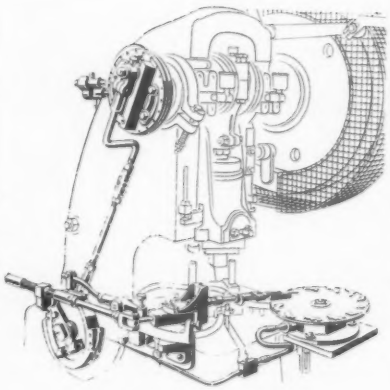
★ *Enlarged view of the "working end" of a sparking plug*



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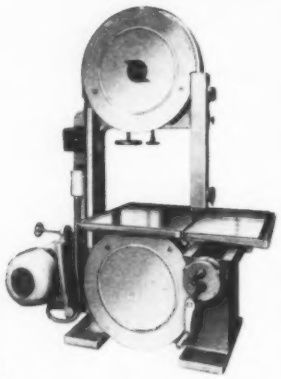
'N.F.' BANDSAW
EIGHT SPEED MACHINE



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DETAILS ON REQUEST

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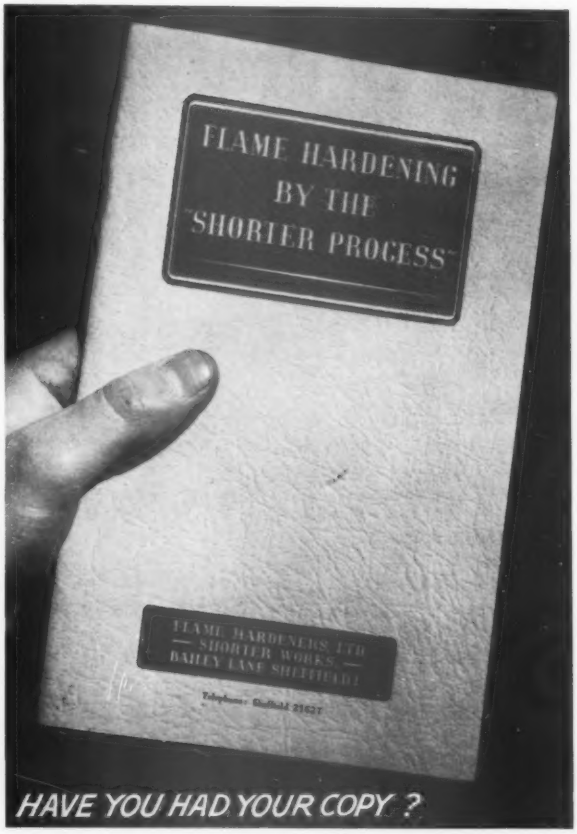
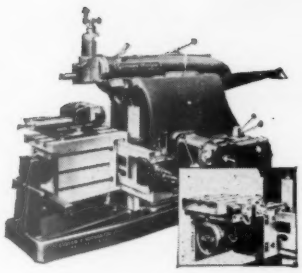


ON THE SPOT SERVICE FOR MIDLAND INDUSTRY

When a manufacturer wants help he does not wish to be kept waiting. His problems are urgent and delays do not improve matters. That is why we restrict our area of operations as works representatives for Mitchell Lathes, Granor Shaping Machines and Lathes and Rushworth Sheet Metal Working Machinery in the seven Midland Counties. Only in this way can we guarantee the on-the-spot service our customers require—a policy which has proved mutually advantageous for many years.



We supply and service Granor high speed Heavy Duty Lathes, 11", 13" and 15" centres.

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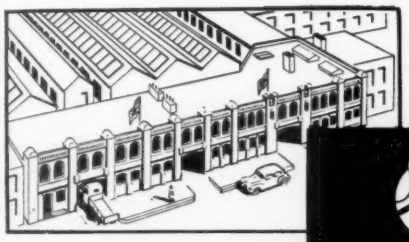

★ **Our technical representatives will be glad to render you all the help and assistance possible. Your enquiries will receive immediate attention.**

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In factories all over Britain GAS INFRA-RED is speeding up processes and cutting production costs. Here is a typical example—3 minutes to dry domestic tinware instead of 30. This result is achieved by 28 Gas Infra-Red panel units, working in conjunction with a floor mounted conveyor and electrostatic spraying plant.

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- *Jaw size $3\frac{1}{2}$ x 1 $\frac{1}{16}$ deep*
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Lang, John & Sons, Ltd.	—
Lang Pneumatic Ltd.	LII
Lapointe Machine Tool Co., Ltd., The	XII
Ley's Malleable Castings Co., Ltd.	—
Lloyd, Richard, Ltd.	—
Lund, John, Ltd.	XL
Lungmuss, H. Louis, Ltd.	LX
Machine Shop Equipment, Ltd.	—
Machinery Publishing Co., Ltd.	—
Magnesium Elektron, Ltd.	—
Marbaix, Gaston, E., Ltd.	XX, XXI
Marsh Bros., & Co., Ltd.	VIII
Marshall-Richards Machine Co., Ltd.	—
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Measuring Instruments (Pullin), Ltd.	—
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Metropolitan-Vickers Electrical Co., Ltd.	—
Midland Iron Co., Ltd., The	—
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JOURNAL SUPPLEMENT

Vol. 33, No. 2
February, 1954

INSTITUTION OF PRODUCTION ENGINEERS, 36 PORTMAN SQUARE, LONDON, W.1

A REMINDER FROM THE SECRETARY

May I take this opportunity to remind members that the Institution's Journal and Journal Supplement fulfil dual purposes: firstly, to convey to members Papers which have been presented to the Institution and, secondly, to convey to members reports of Institution activities and other news items.

The Journal is the most convenient medium for keeping members informed and by making use of it in this way the expense of making separate circulations is avoided. Members are asked, therefore, to pay particular attention to the inserts which are enclosed with some Journals, as well as considering matter published in the body of the Journal.

W. F. S. WOODFORD, *Secretary.*

NORWICH CONFERENCE

A two-day Conference on "Trends in Production Engineering" is being planned by the Norwich Sub-Section, and will take place in Norwich on Friday, 2nd April, and Saturday, 3rd April, 1954.

Three Sessions have been arranged, as follows:—

Session I: "Automatic Transfer Production in Industry" by F. G. Woollard, M.B.E., M.I.Mech.E., M.I.Prod.E., M.S.A.E.

Session II: "Colour Printing Processes and Production in the Printing Industry" by H. J. Jarrold, M.A., J.P.

Session III: "The Future of Electrical Control" by E. M. Langham, A.M.I.E.E.

Summing Up.

In addition to the Lord Mayor and Lady Mayoress of Norwich, many prominent local industrialists have been invited to attend the opening luncheon, which will be held at Samson and Hercules House, Norwich, where the Papers will also be presented. A special Works Visit for ladies attending the Conference has been arranged to take place on the Friday afternoon.

The Conference fee is 25/-, which includes the opening luncheon and tea and morning coffee during the Sessions. Full particulars and application forms may be obtained from the Section Hon. Secretary, Mr. F. H. S. Heidenstam, 33 Cecil Road, Norwich.

"INFORMATION AND THE PRODUCTION ENGINEER"

Joint Conference with ASLIB Aeronautical Group

The Institution of Production Engineers, with the ASLIB Engineering Group, is collaborating in the Third Annual Conference of the Aeronautical Group of ASLIB which is to be held at the College of Aeronautics, Cranfield, from April 2nd to April 5th, 1954.

The theme of the Conference has been selected because it was felt that many Works Libraries cater almost exclusively for design and research staffs. It is hoped that at the Conference, Librarians and Production Engineers will be able to suggest how more production information can be recorded and how it can be made more readily available.

Papers will be presented on "The Reporting and Dissemination of Production Information" and "The Practical Utilization of Production Information".

Speakers who have so far agreed to take part are:

Mr. M. Seaman, M.I.Prod.E., General Manager of British Oxygen Co.
Mr. P. Spear, Grad.I.Prod.E., Director of Research, Rubery Owen & Co. Ltd.
Mr. W. E. Goff, Editor, "Aircraft Production".
Mr. G. Cubitt-Smith, Grad.I.Prod.E., British Electrical Transformer Co. Ltd.
Mr. L. J. Saunders, Grad.I.Prod.E., Glacier Metal Co. Ltd.

On Sunday afternoon there will be a joint session of the Engineering and Aeronautical Groups to consider the matters that have arisen in the previous sessions, while the I.Prod.E. members will visit the Production Department and Work Study School of the College.

A sherry party and the Conference Dinner will be held on the Saturday evening.

There will be a Conference Fee of £1. 1. 0. and accommodation charges will be £1. 7. 6. a day.

Further particulars concerning the Conference together with application forms may be obtained from the Secretary, Institution of Production Engineers, 36, Portman Square, London, W.1.

A.S.T.E. INDUSTRIAL EXPOSITION, 1954

As reported in the Journal last month, the American Society of Tool Engineers will hold its 10th biennial Industrial Exposition in the Convention Center, Philadelphia, from 26th to 30th April, 1954. The Society announces that machine tool firms in Britain, France, Italy, Switzerland and West Germany have taken space at the exhibition. The most cordial relations have existed between the A.S.T.E. and the I.ProdE. for many years, and the Society has issued an invitation to the Institution to visit the Exhibition. The President, Mr. Walter Puckey, Kt., is planning to attend and he suggests that if any other members are also contemplating visits to the U.S.A. about that date, he would be glad to lead an official team from the Institution.

Members who would like to be included in this team should inform the Secretary without delay at 36, Portman Square, London, W.1.

MEETINGS

Visitors tickets may be obtained from Section Honorary Secretaries

FEBRUARY 1st to 28th, 1954.

BIRMINGHAM **7 p.m. FEBRUARY 17th**
The James Watt Memorial Institute, Great Charles Street, Birmingham.
"Developments and Applications in the Manufacture of Glass Fibres" by J. B. Mitford.

BIRMINGHAM GRADUATE **7 p.m. FEBRUARY 9th**
The James Watt Memorial Institute, Great Charles Street, Birmingham, 3.
"Planning for Production" by B. C. Harrison, M.I.Prod.E.

BIRMINGHAM GRADUATE **7 p.m. FEBRUARY 19th**
Visit to British Oxygen Co. Ltd., Wolverhampton.

COVENTRY **7 p.m. FEBRUARY 24th**
The Geisha Cafe, Hertford Street, Coventry.
"Film Evening".

COVENTRY GRADUATE **7.30 p.m. FEBRUARY 25th**
Room A5, The Technical College, Coventry.
"Management Forum". Speakers: H. R. Bingham, C. H. Unwin, J. Munro Fraser.

CORNWALL **7.15 p.m. FEBRUARY 24th**
The Cornwall Technical College, Trevenson Park, Pool Redruth.
"Film Evening"—A programme of sound films on the latest "Production Engineering Methods, Processes and Techniques", introduced by members of the Section Committee.

DERBY **7 p.m. FEBRUARY 15th**
The College of Art, Green Lane, Derby.
"Any Questions". A panel will express their views on subjects submitted by members.

DONCASTER **7 p.m. FEBRUARY 23rd**
The Danum Hotel, Doncaster.
Inaugural Meeting. Address by The President of the Institution, Mr. Walter Puckey, Kt.

EASTERN COUNTIES **7.30 p.m. FEBRUARY 12th**
The Diocesan Hall, Tower Street, Ipswich.
"The Structure of Production Management" by M. Seaman, M.Sc., M.I.Mech.E., A.M.I.E.E., M.I.Prod.E.

EDINBURGH **7.30 p.m. FEBRUARY 17th**
The North British Station Hotel, Edinburgh.
"Electronics in Industry" by G. Horsfall. The talk will be accompanied by a short colour film on Induction Heating.

GLASGOW **7.30 p.m. FEBRUARY 18th**
The Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2.
"Spheroidal Graphite Cast Iron" by A. B. Everest, Ph.D., F.I.M.

GLOUCESTER & DISTRICT **7.15 p.m. FEBRUARY 12th**
The Wheatstone Hall, Gloucester.
"Some Applications of Automatic Controls in Industry" by R. Parr, B.Sc. (Joint Meeting with the Gloucestershire Engineering Society.)

HALIFAX **6.30 p.m. FEBRUARY 8th**
The Grand Hotel, Sheffield.
Regional Meeting. "Some Recent Developments in Engineering" by Dr. T. E. Allibone, F.R.S.

HALIFAX **7.15 p.m. FEBRUARY 16th**
The White Swan Hotel, Halifax.
"Foundry Mechanisation and Improved Methods of Production" by G. W. Nicholls, M.I.B.F., A.M.I.Prod.E.

HALIFAX **7 p.m. for 7.30 p.m. FEBRUARY 26th**
Dinner and Dance at the George Hotel, Huddersfield.

HALIFAX GRADUATE **7.15 p.m. FEBRUARY 9th**
The White Swan Hotel, Halifax.
Production Panel—Members questions will be put to a panel of experts.

LEICESTER **7 p.m. FEBRUARY 11th**
The Windsor Room, Bell Hotel, Leicester.
Annual General Meeting and Films: "Built for the Job"; "Oil and Industry"; "Hydraulics"; "An Introduction to the Heat Engine". Films to be introduced by Mr. A. M. Watt (Shell-Mex and B.P. Ltd.).

LINCOLN **7.30 p.m. FEBRUARY 23rd**
"Production and Inspection of Gears" by J. Milwain, M.I.Prod.E., M.I.E.I. Joint Meeting with Grantham Engineering Society.

LONDON **7 p.m. FEBRUARY 4th**
The Old Ship Hotel, Brighton, Sussex.
"Mechanical Handling Techniques" (illustrated by films) by J. Bain, A.M.I.Mech.E., M.I.B.F., A.M.I.Prod.E.

LONDON **7 p.m. FEBRUARY 11th**
The Royal Empire Society, Northumberland Avenue, Craven Street Entrance, London, W.C.2.
"Figures as an aid to the Production Engineer" by T. Whitwell, F.I.A., F.I.S., F.S.S., F.R.A.S.

LONDON **FEBRUARY 17th**
Annual Dinner at the Connaught Rooms, London, W.C.

LONDON GRADUATE **7.15 p.m. FEBRUARY 18th**
The Institution of Production Engineers, 36, Portman Square, London, W.1.
"Special Purpose Machine Tool and Unit Construction" by J. C. Z. Martin, Grad.I.Prod.E.

LUTON **7.15 p.m. FEBRUARY 23rd**
The Small Assembly Room, Town Hall, Luton.
"Optical Measurement" by J. H. Hobbs.

LUTON GRADUATE **7.30 p.m. to 9.30 p.m. FEBRUARY 10th**
The Luton Library Lecture Hall, Williamson Street, Luton.
"The Rise of the Trade Unions" by J. E. Mortimer.

MANCHESTER **7.15 p.m. FEBRUARY 22nd**
The Reynolds Hall (Room C.3), College of Technology, Sackville Street, Manchester.
"Machine Tools" by J. H. Rivers.

MANCHESTER GRADUATE **7.15 p.m. FEBRUARY 8th**
The Reynolds Hall (Room C.3), College of Technology, Sackville Street, Manchester, 1.
"Production Engineering Research with Special Reference to Metal Cutting" by K. J. B. Wolfe, M.Sc., F.R.I.C., F.I.M.

NORTH EASTERN **7 p.m. FEBRUARY 15th**
The North of England Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle-upon-Tyne.
"Horizontal Boring" by R. Hallam.

NORTH EASTERN **FEBRUARY 25th**
Dinner and Dance at the Old Assembly Rooms, Westgate Road, Newcastle-upon-Tyne.

NORTH EASTERN GRADUATE
7 p.m. FEBRUARY 19th
The North of England Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle-upon-Tyne.
"Time and Motion Study" by a representative of Thos. Hedley & Co. Ltd.

NORWICH **7.30 p.m. FEBRUARY 19th**
Yarmouth Technical Institute.
A Film Show to include films on "Materials Handling" (G.E.C. New York).

NORTHERN IRELAND **7.30 p.m. FEBRUARY 4th**
The Royal Avenue Hotel, Belfast.
Informal Meeting.

NOTTINGHAM **7. p.m. FEBRUARY 3rd**
The Victoria Station Hotel, Milton Street, Nottingham.
"Some Researches in Deep Drawing" by Professor W. H. Swift, M.A., D.Sc.(Eng.), M.I.Mech.E.

OXFORD **7.15 p.m. FEBRUARY 16th**
The Town Hall, Oxford.
"Cold Forming of Light Alloys" by D. A. Barlow, B.Sc.

PETERBOROUGH **7.30 p.m. FEBRUARY 2nd**
The Campbell Hotel, Bridge Street, Peterborough.
"Design for Welding" by Murex Welding Processes Ltd.

PETERBOROUGH **7.30 p,m. FEBRUARY 9th**
The Grand Hotel, Peterborough.
"Productivity" by W. Coutts Donald, C.A., F.C.W.A. (Joint Meeting with the Institute of Cost and Works Accountants.)

PRESTON **7.15 p.m. FEBRUARY 10th**
The Victoria and Station Hotel, Preston.
"Noise and Vibration in Industry" by Dr. A. J. King, M.Sc.Tech., M.I.E.E., F.Inst.P.

READING **7.30 p.m. FEBRUARY 4th**
The Canteen, Transport Equipment (Thornycroft) Ltd., Worting Road, Basingstoke.
"The Fundamentals of Production Management" by M. Seaman, M.Sc., M.I.Mech.E., A.M.I.E.E., M.I.Prod.E.

ROCHESTER & DISTRICT
7.30 p.m. FEBRUARY 11th
The Rotary Room, Sun Hotel, Chatham.
"Metallurgical Control in the Hardening Shop" by M. Glasby, A.Met.

SHEFFIELD **6.30 p.m. FEBRUARY 8th**
The Grand Hotel, Sheffield.
Regional Meeting. "Recent Research Developments in Engineering" by Dr. T. E. Allibone, F.R.S.

SHEFFIELD **6.30 p.m. FEBRUARY 22nd**
The Grand Hotel, Sheffield.
Informal Meeting.

SHEFFIELD GRADUATE **7 p.m. FEBRUARY 15th**
The Sheffield College of Commerce and Technology, Dept. of Engineering, Pond Street, Sheffield.
"Planning for Batch Production" by B. C. Harrison, M.I.Prod.E. Illustrated by lantern slides.

SHREWSBURY **7.30 p.m. FEBRUARY 24th**
The Walker Technical College, Oakengates, Salop.
"Modern Methods of Production of Agricultural Castings" by G. W. Nicholls, A.M.I.Prod.E. Illustrated by a film.

SOUTHERN **7.15 p.m. FEBRUARY 18th**
The Polygon Hotel, Southampton.
"Cincinnati Hydrotel Milling Machines" by S. C. Fenton.

SOUTH ESSEX **7.30 p.m. FEBRUARY 9th**
The Public Library, Duke Street, Chelmsford.
Joint Meeting with the Institute of Industrial Supervisors.

SOUTH ESSEX **7.30 p.m. FEBRUARY 17th**
The Ilford Bowling Club, Ilford.
"High Productivity—the Key Features of American Production Management" by L. J. Saunders, Grad.I.Prod.E.

STOKE-ON-TRENT **7.30 p.m. FEBRUARY 15th**
The Hanley Town Hall, Hanley, Stoke-on-Trent.
"Hot Press Forging" by H. E. Hows, M.Inst.B.E.
Supported by a colour film.

SOUTH WALES **6.45 p.m. FEBRUARY 25th**
The South Wales Institute of Engineers, Park Place, Cardiff.
"Practical Gear Production" by L. Westley Smith, M.I.Prod.E., M.Inst.B.E.

WESTERN **7.15 p.m. FEBRUARY 17th**
The College, Swindon.
"Modern Methods of Measuring—Mechanical and Otherwise" by R. S. Marriner.

WESTERN **7.15 p.m. FEBRUARY 24th**
The Marlborough Room, The Grand Hotel, Broad Street, Bristol, 1.
"Production in the Boot and Shoe Industry" by J. H. Britton.

WESTERN GRADUATE **7.30 p.m. FEBRUARY 1st**
The Grand Hotel, Broad Street, Bristol, 1.
"Some Recent Developments in Engineering Metrology" by C. O. Taylerson, M.B.E.

WESTERN GRADUATE **7.30 p.m. FEBRUARY 25th**
The Wheatstone Hall, Gloucester.
"Investment Casting Technique" by D. B. F. Tedds, F.I.M.

WEST WALES **7 p.m. FEBRUARY 12th**
The Central Public Library, Alexandra Road, Swansea.
"Increasing Productivity" by Professor H. O'Neill, D.Sc.

WEST WALES **7 p.m. FEBRUARY 26th**
The Mackworth Hotel, Swansea.
"Machine Tools for Precision Work in the Clock and Watch Industry" by H. Matthews, A.M.I.Prod.E., F.B.H.I. (Co-ordinated meeting sponsored by the British Horological Institute and the Institution of Production Engineers.)

WOLVERHAMPTON **7.15 p.m. FEBRUARY 3rd**
The Wolverhampton and Staffordshire Technical College, Wolverhampton.
"Electronics in Production Engineering" by D. R. Whatley, B.Sc.(Eng.).

WOLVERHAMPTON GRADUATE
7.30 p.m. FEBRUARY 23rd
The Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
"The Mechanical Gauging and Inspection of Machine Parts" by L. Hare, G.I.Mech.E.

YORKSHIRE **6.30 p.m. FEBRUARY 8th**
Regional Meeting at the Grand Hotel, Sheffield.
"Some Recent Research Developments in Engineering" by Dr. T. E. Allibone, F.R.S.

YORKSHIRE **7 p.m. FEBRUARY 16th**
The Hotel Metropole, Leeds.
"Tracer Control of Machine Tools" by J. Lund, M.I.Prod.E.

YORKSHIRE GRADUATE **7 p.m. FEBRUARY 9th**
Works Visit to Greenwood & Batley Ltd., Armley Road, Leeds.

March 1st to 6th, 1954.

COVENTRY GRADUATE **7.30 p.m. MARCH 2nd**
The Hare and Squirrel Hotel, Cow Lane, Coventry.
Douglas D. Davis Award Meeting.

GLASGOW **7.30 p.m. MARCH 4th**
The Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2.
Annual General Meeting and Open Discussion.

LONDON **7 p.m. MARCH 4th**
Powers-Samas Accounting Machines Ltd., Aurelia Road, Croydon, Surrey.
"Production Control as Applied to Small and Medium-Sized Companies" by F. T. Hunter, A.C.A., A.C.W.A. (Joint Meeting with Croydon and District Sub-Branch, Institute of Cost and Works Accountants.)

NORTHERN IRELAND **7.30 p.m. MARCH 4th**
The Royal Avenue Hotel, Belfast.
Annual General Meeting and Informal Evening.

NOTTINGHAM **7 p.m. MARCH 3rd**
The Victoria Station Hotel, Milton Street, Nottingham.
Annual General Meeting followed by films.

READING 7.30 p.m. **MARCH 4th**
The Great Western Hotel, Reading.
"The Shell Moulding Process" by D. N. Buttrey, M.Sc., A.R.I.C., A.P.I.

SOUTHERN 7 p.m. **MARCH 3rd**
The Municipal College Annexe, Portsmouth.
"Machineability of Steel" by K. J. B. Wolfe, M.Sc., F.R.I.C., F.I.M.

YORKSHIRE GRADUATE 2.30 p.m. **MARCH 6th**
The Great Northern Hotel, Leeds.
Short Papers for President's Prize. "Special Machines as an Aid to Production" by R. Bailey, Grad.I.Prod.E., and "Increasing Production from Existing Machines by using Hydraulic Duplicating Attachments" by G. C. Wadsworth, Grad.I.Prod.E.

PRODUCTION APPOINTMENTS

BULLETIN No. 41

This bulletin is circulated to all members of the Institution monthly as near as possible to the first of the month. Firms or organisations wishing to insert notices in the bulletin should communicate with the Secretary at 36, Portman Square, London, W.1.

The last date for receiving material for insertion in the following month's bulletin is the 20th of each month.
The fee for insertion of particulars regarding each appointment is £3 3s. (up to 100 words), and over 100 words £5 5s. No charge is made to firms affiliated to the Institution, Technical Colleges, Universities and similar organisations.
Advertisers are advised that better response is likely if, in addition to essential qualifications, the following information is given:-
(*a*) Location of appointment; (*b*) Status in the organisation and scope of promotion; (*c*) Salary range and age range.
Advertisers are asked to advise the Institution when vacant appointments are filled. The Institution reserves the right to refuse or withdraw any announcement and also to make any alteration in the wording to ensure conformity with Institution standards.
Members interested in the following appointments should make application in accordance with the terms of notice. No correspondence can be undertaken by the Secretary other than the forwarding of replies to Box Nos.

Hoover (Electric Motors) Limited, Cambuslang, Lanarkshire, have the following vacancies in their Production Engineering Department:—
Draughtsman. Must be experienced in the design of safety guards for all types of small to medium machine tools. Preference would be given to men with previous experience in the design of various safety appliances normally associated with the light engineering industry.
Draughtsman Checker. Must have at least six years' experience in the design and/or checking of press tools and jigs and fixtures used on mass production in light engineering. Only first-class craftsmen will be considered.
Senior and Junior Jig and Tool Draughtsmen. Applicants must have previous experience on jig and tool work in light engineering industry.
Senior and Junior Press Tool Draughtsmen. Previous experience on press tool design work essential.
Methods Engineers. Experience in machining and assembly of electro-mechanical engineering products essential. Higher National Certificate and tool design experience desirable.
Applications for any of the above vacancies should be made in writing to the Employment Officer.

Works Engineer for dry battery factory in India, preferably with long experience in maintenance of machinery for mass production of flashlight cells. Some time study experience desirable. Apply by air mail giving full details of age, experience and salary required to Estrela Batteries Limited, Post Bag 6602, Bombay 19, India.

Manufacturing or Methods Engineers and Product Development Engineers. Progress in manufacturing methods and techniques, in connection with a wide range of products from heavy power station equipment to electronic apparatus and development work on the products themselves, have led to several interesting vacancies in The English Electric Co. Ltd., Stafford, for Manufacturing or Methods Engineers and Product Development Engineers. Applications are invited from engineers working in either of these capacities and from those who have a sound background of practical experience in a manufacturing industry, at least O.N.C., and a desire to enter either of these important branches of engineering. Please write, giving full details of qualifications and experience and quoting ref. S.A.36, to Dept. C.P.S., 336/7, Strand, W.C.2.

Production Engineer required, age about 35 to 45, to act at the onset as assistant to General Manager, with excellent opportunities when ability has been proved of attaining a specific post in the organisation. Must have had workshop training, have a good knowledge of operation layouts and jig and tool design. A strong personality, good education and administrative experience are essential. Please suggest salary expected. The post is available in a large engineering works in the Stockport area. A pension scheme is in operation. Apply giving all relevant information but with no original documents, to Box No. 733, I.Prod.E., 36, Portman Square, London, W.1.
Time Study Engineer required by a large Rubber Company in London area. Applicants should be fully experienced applying incentives to individual and grouped operations, and should be capable of introducing incentive schemes on engineering projects where skilled and semi-skilled labour is employed. Write, giving full particulars of education, experience, age and salary required to Box No. 734, I.Prod.E., 36, Portman Square, London, W.1.

Jig and Tool Draughtsman required by Hertfordshire Electrical Manufacturers. State age, experience and salary required to Box No. 736, I.Prod.E., 36, Portman Square, London, W.1.

Senior and Junior Planning Engineers. Rolls-Royce Limited, Oil Engine Division, require Senior and Junior Planning Engineers. Applicants must have served apprenticeship and be fully conversant with planning for latest production methods. Apply giving details of experience, qualifications and salary required to Labour Manager (PE), Rolls-Royce Ltd., Derby.

Production Engineer required by well known Company employing 1,000; essential qualification includes wide experience in this sphere in all its aspects as applied to production of medium sized machined components. Successful applicants must have had previous experience in charge of Jig and Tool Design, Process Planning, Plant Layout, including mechanical handling, estimating and ratefixing. Applications giving full details of past experience, present remuneration and salary expected should be addressed to the Managing Director, Box No. 737, I.Prod.E., 36, Portman Square, London, W.1.

Senior Draughtsman required for interesting work developing new projects for production. Experience on industrial trucks or allied equipment desired, O.N.C. or H.N.C. preferred. Basingstoke area, housing assistance if required. Write stating age, qualifications, previous experience, married/single, salary, etc., to Box No. 738, I.Prod.E., 36, Portman Square, London, W.1.

Time and Methods Engineer. Applications are invited for the position of Time and Methods Engineer in a firm employing approximately 500 at the main works engaged mainly on the production of specialised pipework for Power Stations. This position entails responsibility for Factory Layout, Planning, Production Methods, Material Handling and Time Study. Applicants are expected to state experience, age and salary required, to the Secretary, Aiton & Co. Ltd., Stores Road, Derby.

Works Manager. A well known Engineering Manufacturer in Yorkshire requires Works Manager for factory employing

3,000. Essential requirements are first class practical knowledge of modern tooling and machine shop, press shop and assembly methods. Must be good disciplinarian, able to handle labour and control all works staff and functions. Substantial four-figure salary. Write in confidence to Box IPEJ 878, LPE, 110, St. Martin's Lane, London, W.C.2.

Senior and Junior Jig and Tool and Die Designers wanted, good conditions with top rates of pay for experienced men. Write Box No. 739, I.Prod.E., 36, Portman Square, London, W.1.

Jig and Tool Draughtsmen. Housing assistance available for Jig and Tool Draughtsmen to work on general machine shop tooling and assembly rigs, with The English Electric Co. Ltd., Luton. Applicants should have served an engineering apprenticeship and preferably hold H.N.C. or equivalent. Please apply to Dept. C.P.S. 336/7, Strand, W.C.2, quoting ref. 1148E.

Production Engineer. The Zinc Development Association requires a production engineer with practical works experience and some business training, for work on increased productivity in the galvanising industry. The post is permanent and pensionable and only fully experienced men need apply. Salary according to qualifications, but not less than £1,000 per annum. The work will involve an initial visit to the United States and subsequent visits to European and U.K. firms. Applications in writing to the Association, Lincoln House, Turl Street, Oxford.

Draughtsmen. Wanted two structural draughtsmen, preferably experienced in structural work and ducting for Power Stations, also a fan draughtsman and designer, experience in dust collecting useful. To commence work at Stroud on 1st March. Write Prat-Daniel (Stanmore) Ltd., c/o Lightpill Iron Works, Stroud, Glos.

Divisional Superintendent. Applications are invited from qualified production engineers for the above position which involves control of a manufacturing division in all its aspects. Essential requirements are: Higher National Certificate, membership of one of the Senior Institutions, apprenticeships, shop experience in high precision engineering and experience of tool design, planning, progressing, stores, material and tool control. The factory is modern and working conditions are excellent. Superannuation and profit sharing schemes apply. State full particulars and salary required to: Personnel Officer, Lockheed Hydraulic Brake Co. Ltd., Shaw Road, Speke, Liverpool, 19.

Jig and Tool Draughtsmen required for engineering factory in Lancashire, experience Jig and Tool Draughtsmen, age approx. 25–30. Minimum qualifications, Ordinary National Certificate, staff appointment, 5-day week. Apply with all particulars to Box No. 740, I.Prod.E., 36, Portman Square, London, W.1.

Jig and Tool Designers required for Crompton Parkinson Ltd., Chelmsford. Positions suitable for men of 25–35 years, experienced in the design of jigs, fixtures and press tools for medium sized electrical products. Positions are permanent and a first class Superannuation Scheme is in operation. Full details of education and experience to the Personnel Officer, Crompton Parkinson Ltd., Writtle Road, Chelmsford, Essex.

Process Planning/Time Study Engineer. A vacancy exists for an engineer in a light engineering works in Worcestershire. Applicants should have previous experience in both subjects. Write stating experience and qualifications to Box No. 741, I.Prod.E., 36, Portman Square, London, W.1.

Chief Planning Engineer required to take charge of process planning and tool design in an expanding Company engaged on electronic engineering. Directly responsible to the Chief Mechanical Engineer. Exceptional opportunity exists for an outstanding man with experience of radio or telephone production. University graduate preferred but technical qualifications are regarded as secondary to ability. Staff pension scheme. House may be available for successful applicant. Apply Personnel Officer, Airmec Limited, High Wycombe, Bucks.

Work Study Officer. Imperial Chemical Industries Limited, Metals Division, has a vacancy at its Works near Swansea for a Work Study Officer for rolling mill and extrusion plants. Candidates should possess Higher National Certificate and Machine or Fitting Shop experience, preferably with an indentured apprenticeship in engineering and work study training, followed by at least two years' experience. Application forms may be obtained from Assistant Staff Manager, I.C.I. Metals Division, Witton, Birmingham, 6.

Ratefixers. Vacancies exist in large, old-established Engineering Company, North Manchester area. Applicants must have engineering apprenticeship, be first class practical men, have considerable experience of Ratefixing and Time Study and be capable of demonstrating if necessary. Salaries offered are commensurate with the high standard required. Staff position, non-contributory pension scheme. Write giving full details of training, qualifications, experience, age, salary, etc., to Box No. 742, I.Prod.E., 36, Portman Square, London, W.1.

Senior Methods Engineers and Senior Jig and Tool Designers are invited to apply for positions concerned with the manufacture of Gas Turbine Engine Blades at D. Napier & Son Ltd., Acton, London, W.3. Possession of H.N.C. and Press Tool Design experience an advantage. Write with full details quoting ref. 145C to Dept. C.P.S., 336/7, Strand, W.C.2.

Time and Motion Study Engineer required for Light Mechanical Engineering. Applicants must be first class Work Study Engineers, and have had not less than three years' experience of Work Study and the practical application of payment by results. It may be possible to assist with a house. Please write stating age, experience and salary required to the Establishment Director, The Pullman Spring Filled Co. Ltd., Ammanford, Carmarthenshire, South Wales.

Experienced Works Manager, capable of accepting full responsibility for output of modern factory manufacturing mass produced metal articles, required by old-established firm in West Country. Thorough practical knowledge of planning and tool design and latest press shop, assembly and finishing methods essential. Applicants must have experience in labour relations and possess drive and initiative. Write giving full particulars of career and salary required to Box No. 735, I.Prod.E., 36, Portman Square, London, W.1.

Production Manager required by well known group of companies starting new sheet metal working factory in Swansea area. He would be responsible to the Factory Manager for the organisation and planning of the manufacturing processes, and should be capable of installing and controlling press shop, finishing shop, assembly department, tool room and all ancillary services in a growing concern. Write in confidence stating age, qualifications and experience to Box No. 743, I.Prod.E., 36, Portman Square, London, W.1.

Methods Engineers. A modern light engineering works, situated in pleasant surroundings in the West, has vacancies for trained Methods Engineers. Applicants should have served a full apprenticeship and preferably have had Tool Room and Jig and Tool Drawing Office experience. Knowledge of Bar and Chucking Autos, Capstans, Milling machines and general machine shop equipment engaged on large batch production, an advantage. Excellent welfare advantages and immense scope for advancement. Ages between 28 and 45 years. Interviews will be arranged locally after consideration of initial application. Box No. 744, I.Prod.E., 36, Portman Square, London, W.1.

Production Engineer. Applications are invited for a Production Engineer, to be responsible for all aspects of production engineering, including process planning and work study on gas separation plant, compressors and associated equipment. Applicants should have had previous experience in the chemical plant engineering field, and have worked in close association with design and development teams on production development. The post is a responsible

one, with scope for advancement. Applications should be addressed to the Personnel Manager, British Oxygen Engineering Limited, Angel Road, Upper Edmonton, London, N.18.

Industrial Engineering. An interesting opening occurs in the Industrial Engineering department of a progressive manufacturing Company (2,000 employees) in the Greater London area. The position calls for a man who has been thoroughly trained in the latest techniques of work measurement and method study, and who has a good record of achievement in their application within a modern industrial concern. It entails also the solution of problems in the wider field of industrial engineering as a service to production management. Candidates should be under 36 years of age; they must have a University degree or equivalent qualification in Mechanical Engineering and have served a recognised apprenticeship. They should also possess the faculty of objective criticism matured by not less than three years' successful experience directly in industrial engineering. The commencing salary will be not less than £1,250 per annum, plus non-contributory Pension and other benefits. This is an exceptional opening with very good prospects for the right man. Please apply in confidence, giving a concise account of education, experience and salaries earned, to Box No. 745, I.Prod.E., 36, Portman Square, London, W.1.

Factory Manager required by old-established Manufacturers, in the Midlands, of high quality precision products in precious and non-ferrous metals. Applicant must possess administrative ability with technical training and wide experience. Ample scope for initiative and progress. High salary and bonus offered to the right man. Applications giving full details of age and qualifications, etc., together with details of previous experience in chronological order should be addressed in the strictest confidence to Box No. 746, I.Prod.E., 36, Portman Square, London, W.1.

Ratefixer/Estimator. Rolls-Royce Limited, Oil Engine Division, Derby, require Ratefixer/Estimator immediately. Applicants should be conversant with latest time study methods and capable of pre-production estimating. Apply giving details of experience, qualifications and salary required to Labour Manager (EP), Rolls-Royce Ltd., Derby.

Sales Engineer for tungsten carbide. Applications required London and Home Counties. Preference given, young man of practical experience, good appearance, references. Apply to Box No. 750, I.Prod.E., 36, Portman Square, London, W.1.

Production Manager required by South East London Manufacturing Company, specialising in precision repetition work. Experience of production planning, machine loading, progress costing and general administration are the requirements. Knowledge of Auto Screw Machines would be an added advantage but not a necessity. The position is a progressive one and the salary depends upon age, qualifications and experience. Write in detail to Box No. 747, I.Prod.E., 36, Portman Square, London, W.1.

Production Development Engineer required for Production Engineering Department of batch type production factory. Duties will include implementation of material handling schemes, preparation of factory layouts, and investigation into processing and machining problems. Education to H.N.C. preferred. The work should offer much interest and wide scope to a keen man with practical experience of similar problems in industry. Contributory Pension Scheme. Applications in writing, giving full personal, educational, and industrial experience details, stating salary required and quoting reference number W/PDE, to Personnel Manager, Ferodo Limited, Chapel-en-le-Frith, Via Stockport.

Planning Engineer required for General Engineering Works with foundry, machine shop and hand forging departments. Qualified engineer with experience in jobbing work and knowledge of modern production methods essential. Apply with all particulars to: The Commercial Manager, Brown Lenox & Co. Ltd., Pontypridd, Glam.

Production Engineer required as assistant to Managing Director of Machine Tool Company near Glasgow (approximately 500 employees). Age 30–40; good general education; H.N.C. or equivalent; corporate membership of either Institution of Mechanical or Production Engineers. Must have organising ability and a sound knowledge of modern management practice. Position offers good prospects. Applicants must reside within thirty miles of Glasgow. Apply Box No. 748, I.Prod.E., 36, Portman Square, London, W.1.

Production Engineer. A young engineer is offered a vacancy in a small Company producing high precision aircraft components. Previous experience with a reputable Engineering Company is an essential. Applicants should have a good general knowledge of planning, machine loading and the progressing of production. The factory is situated in the London S.E.3 area. Write giving full particulars to Box No. 749, I.Prod.E., 36, Portman Square, London, W.1.

Production Engineers required by well-established firm in the West Midlands for planning and estimating. Applicants must have had wide experience in automobile mass production methods embodying latest technique. There are three vacancies for men with exceptional experience—one on assembly work, one on fabrication and press tools, and one on general machining. Good prospects, attractive salary, pension scheme and assistance with housing accommodation, where necessary, make these appointments of particular interest. Please write in strict confidence setting out details of training and experience with positions held in chronological order. The advertiser's staff have been notified. Box No. 728, I.Prod.E., 36, Portman Square, London, W.1.

Time Study Engineer. A firm of mass production dress manufacturers require the services of a Time Study Engineer. Please apply, with full particulars of experience and qualifications, to A. Taylor Limited, 2/4 Tottenham Road, Dalston, N.W.1.

Work Study Officer. Good lecturer on Work Study in its broadest sense required for touring demonstration unit, must be an enthusiast with practical experience of application and ability, to talk to all levels of industry on this subject. Salary according to experience. Apply giving full particulars of education, training and experience to: British Productivity Council, 21, Tothill Street, London, S.W.1.